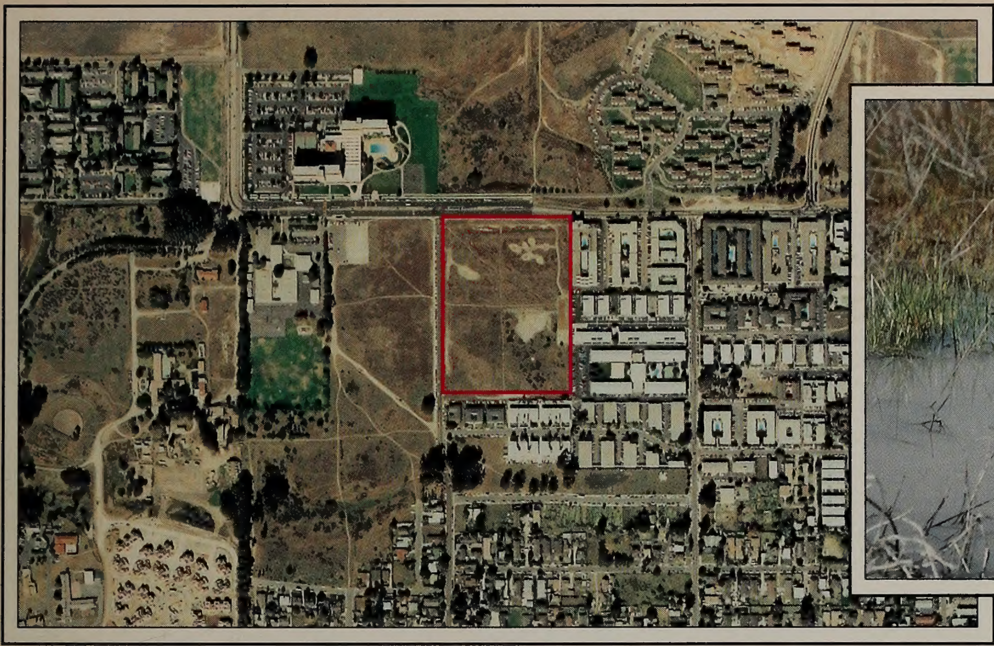

Enhancement, Restoration, and Creation of Vernal Pools

at Del Sol Open Space and Vernal Pool Reserve, Santa Barbara County, California

Environmental Research Team
The Herbarium
Department of Biological Sciences
University of California, Santa Barbara
Environmental Report No. 13 1988

Cover: Top Left: Aerial view (31 Oct 1986) of the northwestern portion of Isla Vista. Del Sol Reserve (outlined in red) is located in the center of the photograph. Disturbed soil from construction activities for the Del Sol Vernal Pool Enhancement Plan is evident within the Reserve. **Top Right:** A Greater Yellowlegs is illustrated wading in one of the restored pools. **Left Center:** One of the created pools two years after excavation and inoculation with seed bank material. Native vernal pool species dominate the lower elevation habitats. **Bottom Left:** *Pilularia americana* (Pillwort) is a regionally rare fern that occurs (center of photograph) in one of the Del Sol vernal pools.

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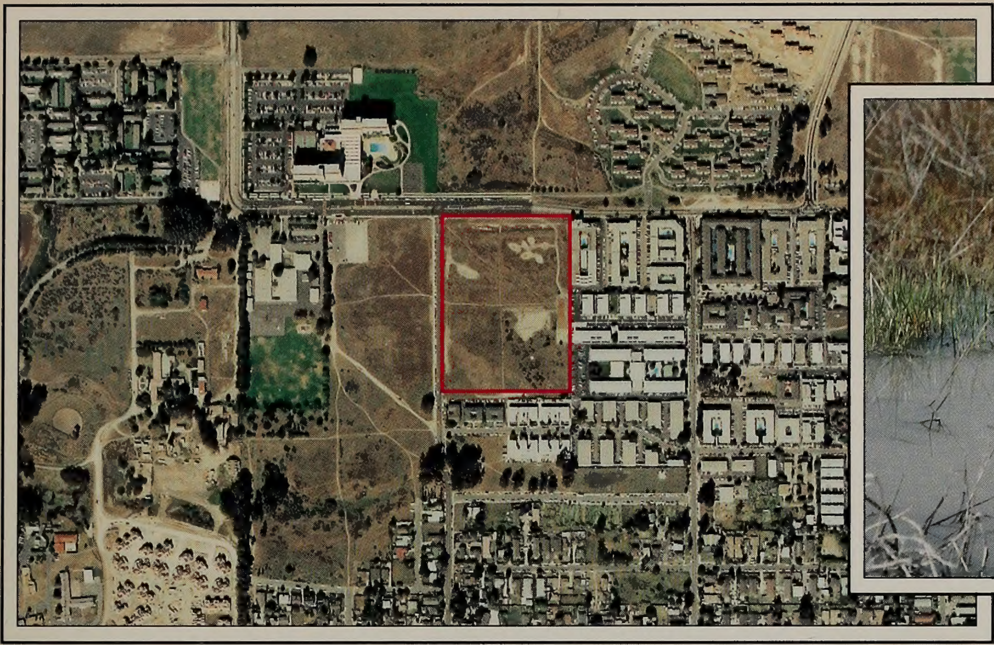

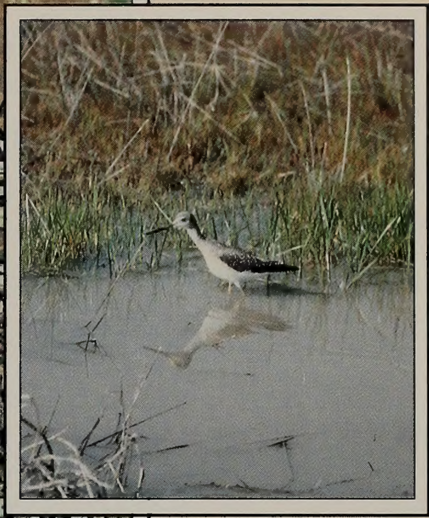

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Enhancement, Restoration, and Creation of Vernal Pools at Del Sol Open Space and Vernal Pool Reserve, Santa Barbara County, California

Report to
Isla Vista Recreation and Park District
and
California State Coastal Conservancy

by

Wayne R. Ferren Jr.

and

David A. Pritchett

Environmental Research Team
The Herbarium
Department of Biological Sciences
University of California, Santa Barbara
Environmental Report No. 13
16 December 1988

F O R E W O R D

This report, "Enhancement, Restoration, and Creation of Vernal Pools at Del Sol Open Space and Vernal Pool Reserve, Santa Barbara County, California", is contribution No. 13 by the Environmental Research Team to the UCSB Herbarium Environmental Report Series. The vernal pool restoration project and monitoring programs were funded by the California State Coastal Conservancy in the form of a subcontract to UCSB from the Isla Vista Recreation and Park District.

The Environmental Research Team is composed variously of UCSB faculty, staff, and students who conduct botanical resource studies that are supported by contracts or grants from local, state, or federal agencies or from foundations or other private groups. Funds for the projects are used to support students and activities of the UCSB Herbarium. The contract and grant program of The Herbarium is one vehicle used to provide services to the public and scientific communities and to enhance our knowledge of botanical resources in California.

The project reported herein was part of the Del Sol Vernal Pools Enhancement Plan that was implemented to improve the environmental quality and interpretive value of publicly-owned open space and to mitigate the historic loss of vernal pools, a type of environmentally sensitive habitat, in coastal Santa Barbara County. This report documents the findings of the preproject, construction, revegetation, and post-project phases of the Enhancement Plan, and includes a brochure and guidebook concerning the Del Sol vernal pools.

Wayne R. Ferren Jr.
Curator
UCSB Herbarium

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Vernal pools are depressions that flood due to winter rains, yet desiccate completely by spring or summer. They are an endangered type of wetland unique to California and other areas with a Mediterranean climate. In 1986, nine vernal pools at Del Sol Reserve were enhanced, restored, or created as part of an ecologic restoration project that also included removal of debris, installation of a short barricade around the site's perimeter, placement of interpretative signs, and publication of a brochure and booklet describing the environmental resources of the site and the restoration project. A Preproject Monitoring Program provided information on the climate, geology, land use history, and soils of the Reserve and a discussion on the origin of the Del Sol vernal pools. Annotated floras of Del Sol Reserve and of all vernal pools in the Santa Barbara area also were produced.

One pool was enhanced by constructing two dams to prevent drainage through ditches and low areas. The dams should increase the depth and duration of flooding, causing a decline in weedy introduced species and an increase in native species, some of which are endemic to vernal pools in California.

Two pools were restored by removing piles of soil and other debris and by excavating the pools to a greater depth than they were before the project. Excavated material was deposited at a disturbed upland, now an elevated observational area. The restored pools are expected to support a greater number of native wetland species than they did before the project.

Six pools were created by excavating depressions into an upland dominated by introduced grasses and underlain by a clay subsoil. Three of the six pools were inoculated with seed bank material obtained from surface scrapings of natural vernal pools; as an experimental comparison, the remaining three pools were not inoculated.

Two years of monitoring indicate that plant cover is establishing well in the restored and created pools. Naturalized grasses, however, persist in the restored and enhanced pools and dominate areas where the soil was disturbed as part of the project and where flooding did not favor the growth of vernal pool plants. The grasses may diminish after several years, especially after years with adequate rainfall. Plant cover and invertebrate animal populations in the inoculated created pools featured high cover and abundances of native vernal pool species. Created pools that were not inoculated supported few vernal pool species.

A review of 16 similar restorational projects or vernal pool sites revealed varying degrees of short-term success of projects in northern, central, and southern California. Although long-term success for restored or created vernal pools is predicted for some sites, it is unknown because of the general lack of data and the mixed results of short-term analyses.

Because there have been two years of inadequate rainfall since the construction phase and because recovery of native vernal pool species was slow in the enhanced and restored pools, we postpone conclusions on the success of manipulations at these sites until a required fifth year of monitoring has been analyzed. We conclude, however, that excavation of depressions at sites with a clay subsoil and subsequent adding of seed bank material from existing vernal pools can result in short-term creation of new vernal pool habitat. The longevity of such new habitats may not be predictable without extended monitoring.

We recommend additional enhancement and restoration of other degraded vernal pools at Del Sol Reserve if results of the fifth year of monitoring show a successful recovery of native vernal pool species. We also recommend a native grassland restoration program and an aggressive maintenance program be conducted to increase and maintain the biological and interpretive values of the site.

I N T R O D U C T I O N

Background

<u>What are vernal pools?</u> Vernal pools are perhaps the most unique, rare, and endangered type of wetland in California (Holland and Griggs 1976; Cheatham 1976; Thorne 1984; Cochrane 1985; Zedler 1987). Other temporary pools occur in various regions of the world (e.g., eastern North America), but the closest analogs to the California pools are located in areas of the world (e.g., South Africa, Chile, Australia) with a Mediterranean climate (Thorne 1984, Zedler 1987). This climate is characterized by mild temperatures, moderate winter rainfall, and a summer drought. Vernal pools form in shallow depressions of various sizes at sites where soils contain an impermeable layer, such as caliche, claypan, hardpan, or other material that produces a perched water table (Thorne 1984). The depressions fill with winter rainfall, but dry completely by spring or summer (Fig. 1). They have been described by Zedler (1987) to have four stages of development during a year: the wetting, aquatic, drying, and drought phases. The organisms that occur in vernal pools must be able to tolerate periods of flooding followed by periods of desiccation. In California, vernal pools are characterized by vascular plants that are endemic or restricted regionally to them. Many other vernal pool plants, however, are aquatic species with widespread distributions. Likewise, most animal species also are widespread, but several recently described species and one new genus of ostracod, a type of crustacean, may be endemic to vernal pools in San Diego County (Zedler 1987).

<u>Distribution of vernal pools</u>. In the Pacific states of North America, vernal pools have been reported from southern Oregon (Holland and Griggs 1976, Kagan 1986) southward into Baja California (Moran 1984). In California, vernal pools occur in two main clusters: 1) on coastal terraces and level topography of lower coastal mountains from Sonoma County (J. Zentner, pers. comm., 1988) south to San Diego County (Figs. 2, 3); and 2) in the Central Valley (Fig. 1) from Shasta County south to Kern County (Holland and Jain 1977, Zedler 1987).

The vernal pools of coastal southern Santa Barbara County (Fig. 4) are an isolated group that occur on flat-topped mesas situated immediately south of the More Ranch Fault. The relatively level topography is an erosional surface that has been uplifted along this fault. The coastal region north of the fault contains a sloping coastal plain, canyons, and rounded foothills to the Santa Ynez Mountains. Included in the Santa Barbara group are: 1) a single pool on More Mesa (Steele 1982); 2) a series of pools (ca. 20) on the Isla Vista Mesa (Pritchett and Ferren 1988); 3) and a series of pools (ca. 16) on the Ellwood Mesa (Thomson 1981), which also is known as Santa Barbara Shores. Vernal pools in the Santa Barbara group vary widely according to size, depth, species composition, and level of disturbance.

<u>An endangered habitat</u>. Because of their occurrence on relatively flat terrain, vernal pools in general have received frequent, widespread, and often devastating perturbations coincident with the spread of agricultural and urban development (Cheatham 1976, 1984; Zedler 1987). Most of the vernal pools of the coastal region of southern California occur in areas favored for development and with high monetary value (Zedler 1987).

Locally, the Santa Barbara vernal pools are restricted to such coastal areas. Most of the original pools of the region have been destroyed during the past three decades of urbanization, particularly by the spread of residential development in Isla Vista and the growth of the University of California, Santa Barbara, onto West and Storke Campuses (Baley and Ferren 1983). All groups of vernal pools remaining in the Santa Barbara complex, however, apparently have been degraded by activities such as grazing, mowing, disking, filling, draining, chemical treatments, and disturbance by off-road vehicles. Zedler (1987) cautions:

> "Ironically, it is just as [vernal pools] are coming to be more widely appreciated that the last remnants are rapidly disappearing. Though the options are closing rapidly, there are still some choices to be made on the size and arrangement of vernal pool preserves. Equally important is the

Fig. 1. VERNAL POOL FROM PIXLEY, TULARE COUNTY, CA. Vernal pools form in minor depressions with an impermeable substrate. They support a biota restricted to these types of habitats. At this site, naturalized grasses (brown) dominate the higher, non-flooded areas, *Lasthenia* (yellow) occurs at the upper elevation within the pool, and *Downingia* (blue) exists at the lower part of the pool. Photo courtesy of J.R. Haller.

Fig. 2. VERNAL POOL (POOL P) FROM ELLWOOD MESA, SANTA BARBARA COUNTY, CA. Vernal pools in the Santa Barbara area do not display striking zones of color as do other pools in California (see Fig. 1). At this site, naturalized grasses and a dicot herb (*Erodium* spp.) dominate the upland outside the pool, but flooded areas support a dense mixture of various herbs (e.g., *Eryngium, Eleocharis, Plagiobothrys,* and *Psilocarphus*). In the Post-project Monitoring Program, data from Del Sol Reserve were compared with data from this pool and another at Ellwood Mesa.

> interrelated question of how the vernal pool preserve will be managed."

<u>Policies regarding Santa Barbara Vernal pools</u>. Vernal pools are treated as an "ecological community of greatest interest" in the Conservation Element of the Santa Barbara County Comprehensive Plan (Santa Barbara County 1979) and are classified as "rare freshwater habitats" that support "highly interesting ecological communities" and have "characteristic and unique biota." The County suggests:

> "Vernal pools' brief seasonal existence represents a marvelous opportunity for the biologist to examine the dynamics of opportunistic species. The pools' extreme susceptibility to disturbance justifies classifying them as unusual and delicate habitats."

All natural vernal pools of southern Santa Barbara County occur within the Coastal Zone. Although the Isla Vista Land Use Plan was "white-holed" or "tabled" by the California Coastal Commission and therefore not implemented, the Isla Vista vernal pools are discussed in the Santa Barbara County Coastal Plan (Santa Barbara County 1982). This Local Coastal Plan recognizes vernal pools as one of the county's Environmentally Sensitive Habitats, which include "...any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments." Environmentally Sensitive Habitats are protected by general and specific policies in the Local Coastal Plan, in addition to state and federal regulations (e.g., the California Environmental Quality Act and the National Environmental Protection Act) that protect many organisms and their habitats.

Concerning the vernal pools, the Local Coastal Plan contains specific statements and policies:

> "Vernal pools are threatened by site development, fire prevention measures, mosquito control activities, mowing, disking, and draining. In an undisturbed state, vernal pools are valuable for scientific and educational purposes. [Policies addressing these vernal pools include:] No

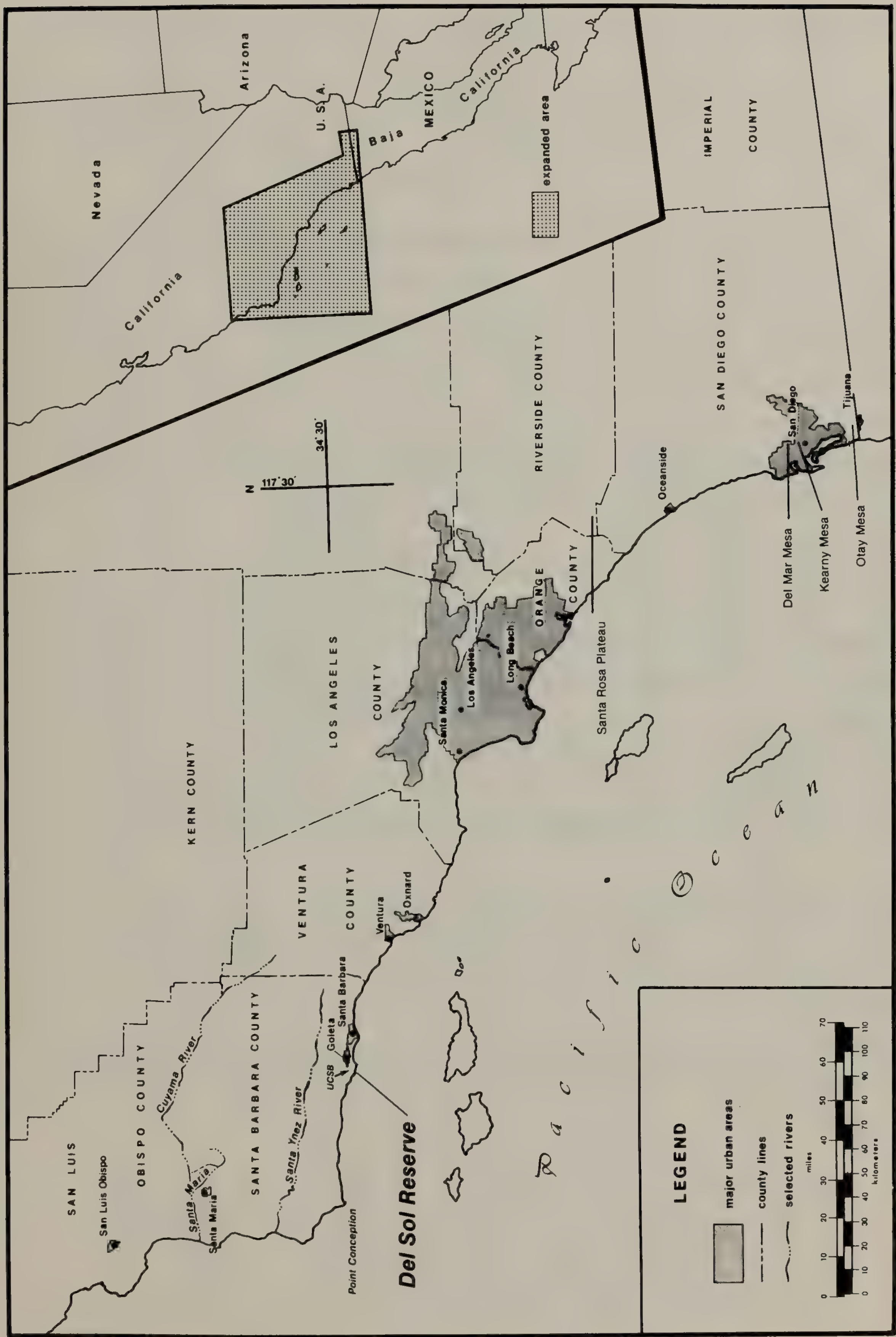

Fig. 3. LOCATION OF DEL SOL RESERVE IN CALIFORNIA. Other vernal pool areas, such as Santa Rosa Plateau, Del Mar Mesa, Kearny Mesa, and Otay Mesa, also are shown.

mosquito control activity shall be carried out in vernal pools unless it is required to avoid severe nuisance.... Grass cutting for fire prevention shall be conducted in such a manner as to protect vernal pools. No grass cutting shall be allowed within the vernal pool area or within a buffer zone of five feet or greater.... Development shall be sited and designed to avoid vernal pool sites..."

Del Sol Open Space and Vernal Pool Reserve. Located in an urban setting in the community of Isla Vista, Del Sol Open Space and Vernal Pool Reserve (Fig. 5) covers 11.78 acres (5 hectares). It is owned and managed by the Isla Vista Recreation and Park District (IVRPD), a local governmental agency. The Del Sol vernal pools are the only pools in the Santa Barbara region presently owned by a public agency. All other sites are owned privately, and virtually all are endangered by proposed residential or commercial developments (SCC 1986).

The Del Sol site was purchased by IVRPD in 1978 and 1979 as three parcels of undeveloped property to be added to the District's "natural open space" parkland designation. Funds for the purchase were part of a bond initiative approved by local voters. The bonds were designated by the IVRPD Board of Directors "for the acquisition and construction of certain District improvements" (IVRPD 1977). With the Del Sol purchase, Isla Vista became one of the first communities in California to set aside property specifically for the preservation of vernal pools.

Isla Vista Recreation and Park District. Isla Vista is an unincorporated community in coastal Santa Barbara County adjacent to and west of the UCSB Campus. The District covers about one square mile and contains approximately 12,000 residents. The IVRPD has a policy of land acquisition for conservation and public recreation, and has had a direct influence on the preservation of natural resources in the densely populated Isla Vista area. According to its Master Plan (IVRPD 1983),

"The purpose of the District is to enhance, improve, and protect the quality of life in the community.... The role of the District shall be to organize the individual resources of Isla Vista's residents into a collective resource. This collective resource shall acquire and preserve natural open space; acquire, develop and maintain

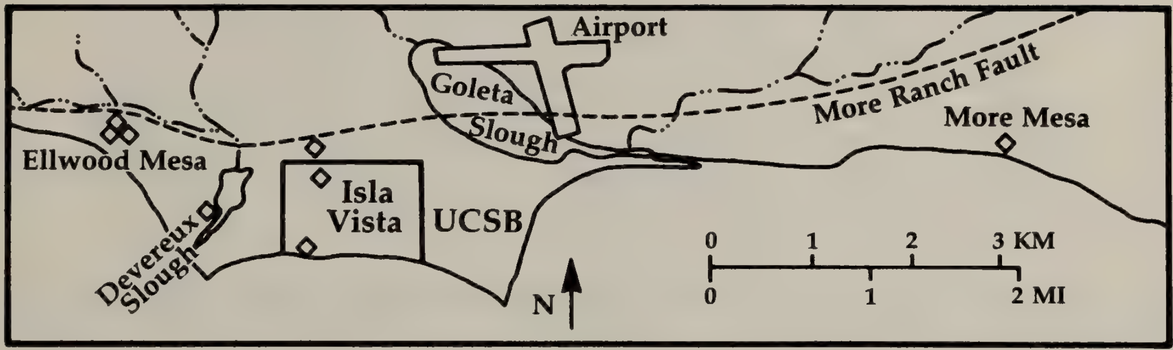

Fig. 4. LOCATION OF VERNAL POOLS IN THE SANTA BARBARA AREA. Individual or groups of pools are denoted by a diamond.

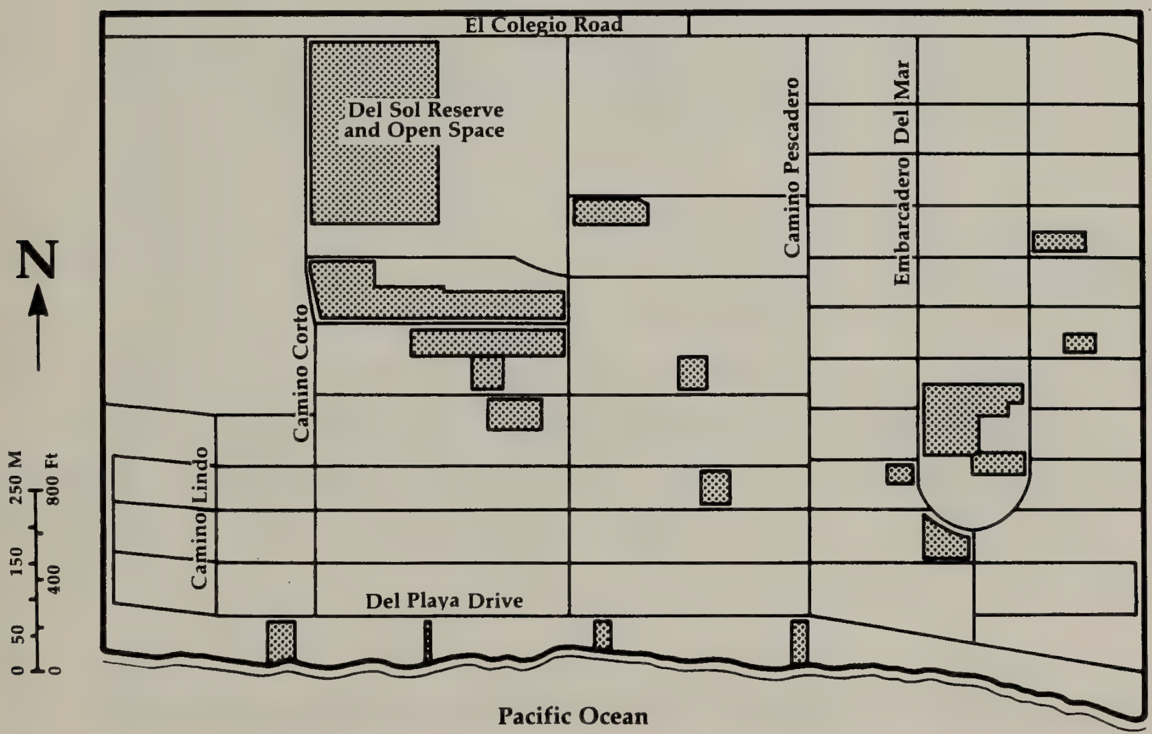

Fig. 5. LOCATION OF DEL SOL RESERVE IN ISLA VISTA. Shaded areas indicate parcels owned by Isla Vista Recreation and Park District.

> parkland; and provide recreational, cultural, and educational opportunities.... At the formation of the District, it was the intent...to maintain a maximum of open space in the District by acquiring vacant land for parks and gardens, as well as for use as natural preserves for the perpetuation of various species of vegetation, insects, birds, and animal life natural to this area..."

Natural Open Space is a specific parkland designation in the Master Plan and is defined as follows:

> "Land or vegetation site which has not been disturbed, improved, interfered with, built upon, affected, or enclosed, except to only further the purposes of this category.... The purpose of Natural Open Space Parks are to provide a wildlife habitat and land in a natural occurring form for the perpetuation of various forms of insects, birds, vegetation, and other animal life natural to this area, and to provide a land resource which promotes human understanding and cooperation with the environment."

Del Sol Open Space and Vernal Pool Reserve is one example of this type of parkland designation. The Master Plan contains specific policies regarding the reserve:

> "[The Del Sol] site contains vernal pools which are to be preserved, protected and enhanced as appropriate. This site is to be enclosed by a wooden fence along the perimeter to block motorized traffic. Informational signs are to be established for the public explaining the significance of the pools. Existing public paths are not to be blocked except to motorized traffic."

<u>California State Coastal Conservancy</u>. With assistance from the Herbarium of the University of California, Santa Barbara (UCSB), the IVRPD applied to the California State Coastal Conservancy (SCC) in 1986 for financial assistance to improve the quality of Del Sol Open Space and Vernal Pool Reserve. The SCC is a division of the Resources Agency of the State of California and was created by the State Legislature in 1976 to help protect and restore the State's resources in the entire Coastal Zone, including the San Francisco Bay. According to the Conservancy (SCC 1983),

> "The responsibilities of the Conservancy fall into seven areas: preservation of agriculture land; coastal restoration; coastal resource enhancement; urban waterfront restoration; preservation of coastal resource areas; public access to the coast; and assistance to nonprofit organizations and land trusts in coastal resource protections.

Improvements in the environmental quality of the Del Sol site are covered best in responsibility number three: "Coastal resource enhancement". The SCC was granted certain powers, by the Legislative Act (State of California 1988) that established it, to fulfill this responsibility. According to Chapter 6 of the Act,

> "The Conservancy may award grants to state agencies, local public agencies, and nonprofit organizations for the purpose of enhancement of coastal resources which, because of indiscriminate dredging or filling, improper location of improvements, natural or human-induced events, or incompatible land uses, have suffered loss of natural and scenic values."

To initiate a project, local governments, other State and public agencies, and nonprofit organizations and land trusts apply to the SCC for funding or technical assistance. All projects sponsored by the Conservancy must conform to the policies and requirements of the California Coastal Act and the California Environmental Quality Act (CEQA).

Del Sol Vernal Pools Enhancement Plan

<u>Why propose site enhancements</u>? Del Sol Open Space and Vernal Pool Reserve is one of only six sites that still support vernal pools in southern Santa Barbara County and is the only site in public ownership. Thus, Del Sol Reserve represents the only current opportunity to assure continued protection of vernal pools. However, the SCC (1986) concluded that,

> "Because the Del Sol site is undeveloped, it gives the appearance of a vacant lot, making it a prime target for illegal entry of vehicles and the dumping of dirt, concrete, abandoned appliances, cars and furniture, and other debris.

Without intervention, the continued ability of this site to support vernal pools will be seriously threatened."

Although the IVRPD Master Plan (IVRPD 1983) recommends the protection of the Del Sol vernal pools, the District has been unable to raise funds to implement its policies. Thus, a proposal to fund site enhancements, which would protect and potentially restore these special wetland habitats, was considered essential by many (e.g., Arnold 1986, Capelli 1986, Ferren 1986, Seymour 1986), before the habitats were degraded further by perturbations such as continued draining of pools, dumping of refuse, and vehicular access.

Project history. In 1981, IVRPD applied to the SCC for a grant to acquire several additional privately-owned parcels in Isla Vista that were known to contain vernal pools (SCC 1981). The "Isla Vista Vernal Pools Enhancement and Management Plan" also proposed to provide habitat improvements at the Del Sol site. Although the project was approved by the Board of Directors of the Conservancy, a contract to IVRPD was not executed because the landowner of the parcels that were targeted for acquisition refused to sell at the appraised value (SCC 1986). Thus, the original enhancement proposals for the Del Sol site were not implemented.

In 1986 at the request of the IVRPD, the UCSB Herbarium submitted a subcontract proposal (Environmental Research Team 1986) for inclusion in the Del Sol enhancement proposal that was prepared for the SCC. Combined proposals by IVRPD and UCSB included various site and habitat improvements.

Del Sol Vernal Pools Enhancement Plan. The vernal pool project recommended by SCC staff (SCC 1986) was entitled "Del Sol Vernal Pools Enhancement Plan" (Appendix I), and in May 1986 a grant of $61,384.00 was awarded to IVRPD to conduct this project. As proposed, the IVRPD would work with the Environmental Research Team of the UCSB Herbarium to implement the habitat enhancement portions of the plan, and with the California Conservation Corps, which would supply workers for removal of

debris and installation of a barricade as a donation of $9,460.00 in addition to the SCC grant. The entire plan included seven tasks, as summarized below:

1. Removal of several tons of illegally dumped refuse consisting of dirt, concrete, abandoned furniture and other debris.

2. Removal of asphalt over a portion of the property that was paved for parking without permission from IVRPD.

3. Enhancement and/or restoration of existing or historic vernal pools and creation of new vernal pools to compensate for past losses on this site.

4. Placement of a low visibility barrier around the perimeter of the property. This will impede vehicle access without blocking pedestrian entrance and will prevent future dumping.

5. Public access improvements consisting of interpretive signing and installation of refuse containers and observation benches.

6. Publication of a layperson's interpretive brochure and guidebook to vernal pools focusing on the Del Sol site. The brochure and booklet will be available at the IVRPD office.

7. Preproject and post-project monitoring of the project site by the Environmental Research Team of the UCSB Herbarium. Objectives are to conduct an inventory of the flora, to locate rare and/or endangered species, to evaluate the response of vegetation to site alterations, and to assess seasonal water levels.

Consistency of the plan with existing regulatory policies. Several State and County guidelines affect alteration of wetlands in the Coastal Zone. Projects proposed for coastal areas must comply with these regulatory policies. The Del Sol Vernal Pool Enhancement Plan met various agency policies as summarized below.

The project was found to be consistent (SCC 1986) with the State Coast Conservancy's resource enhancement program because: 1) it is cost effective as a result of donated labor from the California Conservation Corps and in kind services provided by IVRPD and UCSB; 2) the project is

significant because the rarity and sensitivity of vernal pools, because of the public ownership the Del Sol site, and because of the educational opportunities it provides; 3) the project has broad support from conservation groups, local residents, University staff and students, and government entities; 4) the IVRPD is committed to managing the property in a manner that will ensure the preserve of the Del Sol vernal pools; and 5) all interested parties are eager to proceed with the project. The Conservancy and the County of Santa Barbara also concluded that the project was categorically exempt from requirements of the California Environmental Quality Act guidelines, because the project consists of "...minor alterations of existing public...facilities...or topographic features...for...maintenance of existing...native growth..."

The Del Sol project also is consistent with applicable policies of the California Coastal Act (State of California 1976). Because the Statewide Interpretive Guidelines (California Coastal Commission 1981) on wetlands recognizes vernal pools as wetlands, projects affecting wetlands must comply with Coastal Act policies. Several sections of the Act applicable to the project are:

20231. "The biological productivity and quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of...organisms...shall be maintained and, where feasible, restored."

30210. "Maximum access, which shall be conspicuously posted, and recreational opportunities shall be provided for all the people consistent with...the need to protect...natural resource areas from overuse."

30233. "The diking, filling, or dredging of open coastal waters, wetlands, estuaries, or lakes shall be permitted...where there is no feasible less environmentally damaging alternative, and where feasible mitigation measures have been provided to minimize adverse environmental effects, and shall be limited to...restoration purposes... nature study, aquaculture, or similar resource dependent activities.... In addition to other provisions of this section, diking, filling, or dredging in existing estuaries and wetlands shall

> maintain or enhance the functional capacity of the wetland or estuary..."

30240. "Environmentally sensitive habitat areas shall be protected against any significant disruption of habitat values, and only uses dependent on such resources shall be allowed within such areas."

Based on the compliance of the project with the California Coastal Act Commission's staff recommendation (California Coastal Commission 1986a) of coastal restoration project concluded the following:

> "Vernal pools are a seasonal wetland that are also considered environmentally sensitive habitat. The primary purpose of the project is to restore and enhance the vernal pools' habitat values. A secondary aim is to provide an educational resource... Both objectives are allowable purposes under Section 30233. Educational purposes are dependent on the resources that are being studied, and are allowable purposes under Section 30240. Therefore, the Commission finds that the project is consistent with...the Coastal Act."

The Commission (California Coastal Commission 1986a) also recommended approval because of project compliance with the Local Coastal Program (Santa Barbara County 1982). Commission findings included the following:

> "...the certified Santa Barbara County LCP designates the vernal pool as "environmentally sensitive habitat" and includes a number of policies to ensure long-term preservation. Educational programs and interpretive displays are part of the actions recommended in the LCP. The Commission notes that this site is one of the few remaining areas where vernal pools exist within the coastal zone in Santa Barbara County. The local governments have supported preservation of the habitat through acquisition efforts of the Park District and planning efforts of the County. The Commission finds that support of these local efforts is a high priority goal both to halt the ongoing degradation of the vernal pools and to provide for enhancement for habitat and educational purposes."

Purpose of this Report

The purpose of this document is to report the methods, results, and analysis of three of the seven tasks, as listed previously, of the Del Sol Vernal Pool Enhancement Plan:

Task 3 - Enhancement and/or restoration of existing or historic vernal pools and creation of new vernal pools to compensate for past losses at the Del Sol site.

Task 6 - Publication of a layperson's interpretive brochure and guidebook to vernal pools focusing on the Del Sol site.

Task 7 - Preproject and post-project monitoring of the project site.

Although the Del Sol Vernal Pool Enhancement Plan included other activities that enhanced the quality and protection of the vernal pools (e.g., removal of refuse and construction of a low-profile barricade to motor vehicles) and also provided public access and on-site educational opportunities (e.g., preservation of footpaths, installation of public information signs, and construction of benches and refuse containers at an observation area), this report focuses on the techniques of restorational ecology utilized to complete the project and on the publication of a brochure and guidebook. The Environmental Research Team of the UCSB Herbarium, however, was subcontracted by the IVRPD to help design, supervise, and monitor all tasks of the plan.

We list below the specific objectives of the plan's tasks that are addressed herein:

1. To conduct a preproject monitoring program at the Del Sol site: 1) to summarize the physical environment; 2) to interpret the history of land use; and 3) to summarize existing information on the biological resources.

2. To implement the enhancement and restoration of existing vernal pools by terminating undesirable drainage of some pools and by excavating soil and debris illegally dumped in others.

3. To create vernal pools from upland areas to compensate for the historic loss of vernal pools at the Del Sol Reserve.

4. To implement a revegetation program, including the inoculation of various restored and created pools with seed bank material acquired from existing natural pools.

5. To conduct a post-project monitoring program: 1) to produce a post-project topographic map; 2) to provide an inventory of the vascular plants of the Del Sol site and of vernal pools in general in the Santa Barbara region; and 3) to monitor aspects of the hydrology and flora at natural, enhanced, restored, and created vernal pools.

6. To provide an analysis of the Del Sol Vernal Pool Enhancement Plan for the first and second years after the construction phase.

7. To publish a brochure and guidebook for public information that focus on the Del Sol project and the importance and sensitivity of vernal pools in general.

M E T H O D S

Methods described herein for the Del Sol project are organized according to the seven purposes of this report that are listed in the Introduction. This organization includes five major parts: 1) Preproject Phase; 2) Construction Phase; 3) Revegetation Phase; 4) Post-project (Post-construction) Phase; and 5) Analysis and Publications. Specific sites where parts of the project were performed are noted in Figure 6.

Preproject Phase

<u>Preproject monitoring program</u>. The preproject monitoring program for the Enhancement Plan focused largely on developing a description of the study area (Del Sol Open Space and Vernal Pool Reserve), including: 1) aspects of the physical environment; 2) origin of the vernal pools; 3) land use history of the site; 4) a preproject, topographic and wetland/upland boundary map; 5) analysis of the soil; and 6) a general description of the vegetation and flora.

ENVIRONMENTAL SETTING. To provide a description of the environmental setting of the Del Sol site, we reviewed existing reports for the Santa Barbara region to provide background data on the climate, topographic setting, and geologic origin of Isla Vista Mesa on which the Del Sol site occurs. We made site visits and reviewed historical maps, aerial photographs, and the vernal pool literature to develop a hypothesis on the origin of the vernal pools at the study site as well as throughout the complex of Santa Barbara vernal pools. We also used historical maps, and aerial photographs (UCSB Map and Imagery Lab), written documents, and personal communications to provide an analysis of the land use history of the site and to list the implications this history has on the present composition of the vegetation and flora.

SOIL ANALYSIS. Because the presence of vernal pools is dependent upon an impermeable substrate, we evaluated the nature of the soil at nine locations throughout the Del Sol site (Fig. 6). Soil cores were

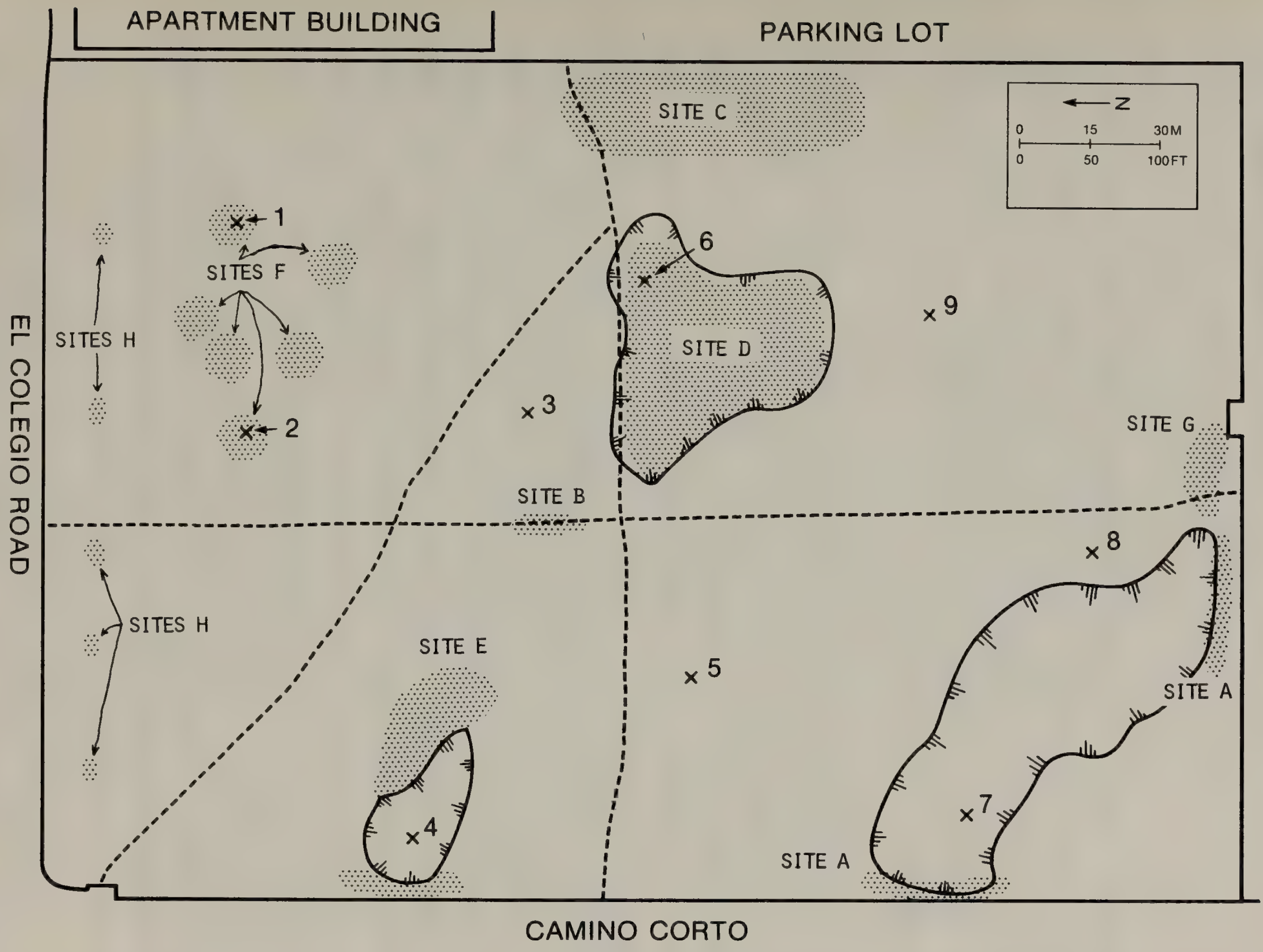

Fig. 6. LOCATIONS OF CONSTRUCTION ACTIVITIES (stippled areas) AND SOIL SAMPLES AT DEL SOL RESERVE. Soil samples are numbered 1 to 9. Foot paths are represented by dotted lines.

extracted by Coast Valley Testing, Inc. (a project subcontractor) in September 1986 (Fig. 7). The cores were sampled to a depth of 2.5 m (8 ft) and were analyzed at 0.5 m intervals for moisture content and particle size distribution. At the UCSB Geography Soils Laboratory, Scott Jones, a UCSB Herbarium Associate and project subcontractor, used the hydrometer method to perform the particle size analysis. At UCSB Department of Biological Sciences, Pritchett used the gravimetric method to determine the moisture content of the soil samples. Identification of the impermeable substrate will enhance our characterization of the Del Sol vernal pools, and will permit us to compare the impermeable layer at enhanced, restored, and created wetland sites, as well as upland sites.

TOPOGRAPHIC MAP. A topography survey of the site was conducted by using a transit on 2-8 July 1986 by Condor Construction Company (a project subcontractor) and D. Pritchett. A preproject topographic map of the site (scale: 1" = 30′, contour interval = 6"), which also included prominent features (e.g., debris piles, trails, and shrubs), was completed on 14 July 1986. Proposed construction activities (i.e., soil to be excavated or deposited for enhancement, restoration, and creation projects) then were indicated on the preproject map. Sites for many of the activities previously had been marked by Ferren and Pritchett in the field with stakes to permit accurate location of them during the survey. A detailed construction map with construction contours and cross sections for proposed activities was not prepared for this project because we decided that staking the areas for excavation and carefully monitoring the process would be sufficient. We had prepared a detailed construction map for our West Campus Project and found it was not necessary as long as monitoring of construction was possible. We did prepare, however, a general grading plan on the preproject map as part of the application for a grading permit from the County Public Works Department.

Ferren and Pritchett also determined preliminary estimates of wetland/upland boundaries when proposed construction activities were mapped. Subsequently, during supervision of the construction phase of

the Enhancement Plan, we mapped in detail the contacts between dominant plant associations characteristic of wetland/upland boundaries. This information was placed on a copy of the preproject topographic map and serves as the baseline "preproject" conditions and the extent of vernal pool wetlands at the Del Sol site.

VEGETATION AND FLORA. Preliminary lists of plant species characteristic of the Del Sol upland and wetland habitats also were prepared as we supervised the construction phase of the enhancement plan. Although herbarium specimens of vernal pool species have been collected by various people over several decades, no comprehensive evaluation of the Del Sol site, particularly of upland habitats, has taken place. Lists of native upland and wetland plants observed during the entire project permit us to estimate the composition of native plant communities before historic and recent disturbance of the area and invasion of habitats by exotic species. Additional preproject information was obtained from historic records, personal observations, herbarium specimens, published information (e.g., Smith 1976) and manuscripts (e.g., Whitmore 1983, Thomson 1981). To record the preproject composition of selected locations within the Del Sol site, Pritchett placed a transect (29 April 1986) through the pool to be enhanced and on 9 July 1986 at a site where wetlands were to be created (Fig. 8). Preproject conditions throughout the site also were recorded with photographs. Preproject observations were used in comparison with data obtained from the post-project monitoring program to help assess the effects of the project.

Construction Phase

Enhancement and restoration of vernal pools. Existing vernal pool habitats that have been degraded by various forms of disturbance (e.g., draining, filling, etc.) were identified by the UCSB Herbarium Environmental Research Team (1986) and were included within the Del Sol Vernal Pools Enhancement Plan (SCC 1986). Proposals for specific improvements were suggested in both of these documents (see Appendix I) and a modified plan was detailed on the preproject topographic map (see: RESULTS - Preproject Monitoring Program).

Fig. 7. EXTRACTION OF SOIL SAMPLES. A project subcontractor used a motorized auger to drill holes for obtaining soil samples at various depths.

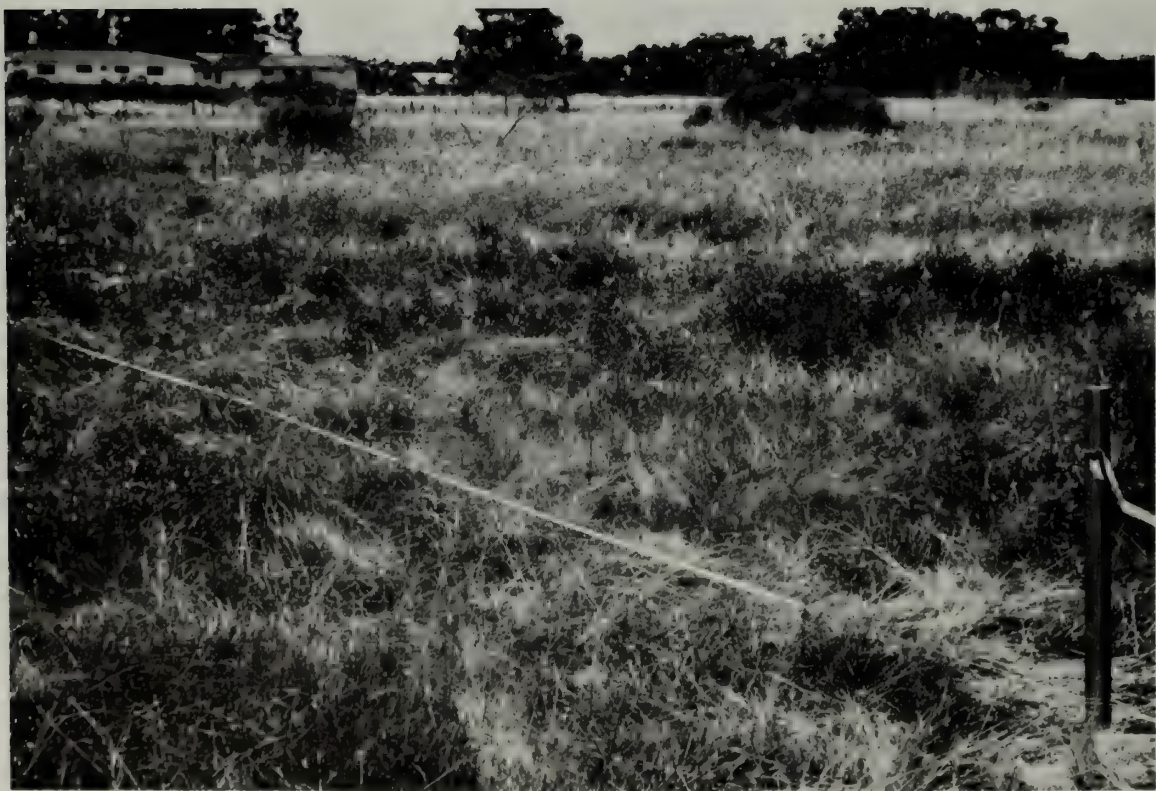

Fig. 8. SITE OF CREATED POOL (POOL H) AT DEL SOL RESERVE. Before excavation, the area of the created pools was a flat upland habitat that supported vegetation dominated by naturalized grasses.

ENHANCEMENT. We define "enhancement" as an act or process that results in an improvement to an existing habitat or ecosystem generally without requiring large-scale alteration of the habitat or ecosystem. The Del Sol project included several types of enhancements: 1) removal of trash from upland and wetland habitats and the placement of trash receptacles for use by visitors to the Reserve; 2) installation of a low-profile barricade (low posts) to keep motor vehicles off the Reserve and, thus, prevent damage from wheel ruts and discharged waste motor oil; and 3) construction of dams on margins of two large pools to prevent the loss of water through an excavated ditch and low topographic area. We emphasize herein only the latter enhancement.

The largest vernal pool in the Del Sol Reserve occurs in the southwest corner of the site along Camino Corto (Fig. 6). Ferren observed that this pool contained a greater cover (ca. 100%) of native hydrophytes, particularly vernal pool species, than during the preproject observations in 1986. Others (e.g., A. Howald, pers. comm., 1987) also have observed that it supported greater numbers of regionally rare species such as Pilularia americana (Pillwort), an aquatic fern, than we have observed recently. At maximum flooding in recent years, this pool drained onto Camino Corto, the adjacent road, because the road is lower than the pool and because a small ditch had been dug to lower the water level and, thus, reduced the maximum level and duration of flooding. The ditch had been excavated by the Goleta Valley Mosquito Abatement District (J. Stannard, pers. comm. 1988) to reduce local mosquito populations, but it was partially filled later. The shorter duration of flooding, however, apparently favored some naturalized plant species such as Lolium multiflorum (Italian Ryegrass), which has become abundant in the pool, whereas some native vernal pool plants are less common now. Bauder (1987) also reports higher frequencies of naturalized species in pools with "low water holding capacity" caused by disturbance and habitat fragmentation. She found some vernal pool species are favored by at least two weeks of flooding, which also prevents or eliminates exotics that cannot tolerate these conditions.

To eliminate the loss of water through the ditch, a low dam (i.e., a soil berm), approximately the elevation of upland habitat, was constructed along Camino Corto for the length of the pool margin (Fig. 9). Prior to construction, the upper 10 cm of soil at the location of the berm was scraped and stockpiled nearby for later use in the revegetation program. A second dam was constructed along the southern margin of the pool to prevent drainage into a parking lot to the south of the site. These berms are designated Site A on the preproject map (Fig. 6).

Although not proposed in the original plan, a third dam was constructed adjacent to a second vernal pool (Fig. 6, near Site E) that occurs in the northwest section of the Reserve. The third dam was constructed to increase the elevation of a narrow upland area adjacent to the lower end of the vernal pool along Camino Corto, thus enhancing the flooding potential of the wetland. Construction of the three dams occurred on 19 and 22 August 1986 and was conducted by Condor Construction Company using a Case Skiploader (model 480LL) tractor and a larger Caterpillar Loader (model 966B). Soil for the dams came from piles that had been formed when the created vernal pools were excavated (Site F). To achieve a smooth surface, final grading was done with the Skiploader, which resulted in more precise contouring.

Following construction of the dams, soil that had been scraped and stockpiled at the dam sites was spread on the pool-side of dams to hasten revegetation. The stockpiled soil contained a seed bank that could initiate plant cover to reduce erosion of freshly exposed soil into the vernal pools. In addition to the elimination of drainage onto Camino Corto, the two western dams also provide a level area (30 ft wide) for a fuel break along the perimeter of the Reserve. Vegetation on this perimeter will be cut each summer as it has in recent years according to County fire policies. IVRPD also periodically discs this perimeter to improve the habitat for _Lupinus bicolor_ (Sky Lupine), an annual herb becoming rare in Isla Vista (M. Kellogg, pers. comm., 1988).

RESTORATION. We define "restoration" as an act or process that results in an improvement to a habitat or ecosystem and often requires large-scale alteration of an area to return it to some previously existing state. The Del Sol project included the restoration of two sites (Fig. 6): 1) a large degraded wetland (Site D) that contained soil piles, asphalt and cement, and refuse such as automobile parts and mattress springs; and 2) a vernal pool (Site E) partially filled with soil piles and concrete blocks.

As with the enhancement portion of this project, the restoration of wetlands was conducted by Condor Construction Company under the guidance of Ferren and Pritchett during the period 18-26 August 1986. Initial grading of sites (Fig. 10) was accomplished with a Caterpillar Loader (model 966B) and refinements and final grading was done with a Case Skiploader (model 480LL) on 23 and 26 August.

A dirt road from El Colegio to an illegally constructed, asphalt parking lot (at the center of the eastern margin of the Del Sol parcel) was formed to provide access for the Loader into the larger of the two restoration areas (Fig. 6, Site D). Material excavated from the two restored pools was used to cover portions of the parking lot. This mounded soil created a flat-topped and elevated observation area (Site C), which now includes three benches, two picnic tables, and two refuse containers. The IVRPD had determined earlier that breakup and removal of the asphalt would be too difficult and costly for existing resources provided by the grants from SCC and the Conservation Corps. Likewise, removal of excavated soil and debris from the Del Sol site also was too costly. Thus, construction of the observation area not only provided opportunities for access and observation, but also provided a means for on-site disposal of asphalt and soil and allowed the various tasks to proceed. Because all construction at the Del Sol site was conducted during the summer when soil is dry, the possibility of excessive dust blowing into residential areas was likely. Therefore, a water truck was used one day to suppress dust and to compact the surface of excavated areas at the restored pool (Site D) and at the observation area (Sites C and G).

Fig. 9. CONSTRUCTION OF A DAM TO ENHANCE A VERNAL POOL. Soil from a restored pool (Pool G) was transported along the western edge of the reserve to construct a dam at Pool N to prevent the pool from draining.

Fig. 10. EXCAVATION OF THE RESTORED POOL (POOL E). A large Caterpillar Loader removed soil piles and other debris to enlarge the depression that is the restored pool. Excavated material was used to construct the elevated observational area.

Grading of the restoration sites was conducted to a depth that approximated existing vernal pool habitats adjacent to the degraded areas. In the case of Site D, however, the larger size of the restored area permitted us to contour the exposed area so that three deeper depressions were surrounded by shallower areas and sites transitional to upland habitats. We predict that the diversity of topographic relief will result in a heterogeneous series of plant associations rather than a single gradation of vegetation from wetland to upland habitats (see: Scheidlinger et al. 1984, Zedler 1987, Pritchett 1986a).

Creation of vernal pools. To partially compensate for the historic loss of wetlands at the Del Sol site, we designed and implemented an experiment to create vernal pools. We define "creation" as an act or process that changes one habitat or ecosystem to another, one that presumably did not exist at the site previously.

At Del Sol Reserve, an upland grassland habitat with subsurface soil layers similar to natural pools at Del Sol was selected as the site to create vernal pool habitat. Six circular depressions (Site F) were dug in the northeastern section of the site (Fig. 6). A Case Skiploader (model 480LL) was used by Condor Construction Company to excavate the depressions (Figs. 11 and 12) at locations we had selected that might provide basins of approximately the same size (ca. 10 m diameter) and depth. Construction occurred on 18-19 August 1986; soil piles were removed to Sites A and C, and final grading was completed on 26 August. The depth of pools was estimated at the average depth of natural pools of the region, which is greater than the average depth of natural pools at Del Sol Reserve.

Excess soil from Site F was used to create the dam near Site E, and was used to improve an existing footpath through a wetland at Site B. This latter improvement will provide access to a frequently used footpath that often is impassible during wet conditions.

ADDITIONAL ACTIVITIES. Using the Skiploader, six additional but smaller depressions (Site H) were constructed on 19 August 1986 inside

the barricade of posts installed along El Colegio Road. These depressions are where IVRPD will plant seedlings or acorns of Quercus agrifolia (Coast Live Oak) during Winter 1988-89. Condor Construction Company completed all construction activities on 26 August 1986.

Revegetation Phase

Revegetation Program. We implemented three approaches to revegetation of soil disturbed as a result of the construction phase of the Enhancement Plan. The revegetation program included: 1) stockpiling and subsequent redistribution of existing soil containing on-site seed bank material; 2) inoculation with seed bank material acquired off-site; and 3) no action to allow natural colonization of disturbed soils.

ENHANCED VERNAL POOLS. Enhancements for Sites A and E (Fig. 6) included disturbances of wetland substrates or seed banks only at the margins of the vernal pools where the dams were constructed. Thus, a revegetation plan for the undisturbed areas of the pools was not proposed. However, revegetation of the dams that were constructed to stop drainage of pools, particularly at Site A, was attempted to reduce erosion of the disturbed soils (see: Construction Phase--Enhancement of vernal pools). Soil containing seed bank from Site A along Camino Corto was spread (by Condor Construction company using a Caterpillar Loader) over the east-facing side of the dam, which slopes into the vernal pool. No stockpiled soil was placed on the top or west-facing side of the dam, on the southern dam at Site A, or on the dam near Site E. We proposed that, following rainfall, seeds in the soil that had been spread over the dam surface would germinate and initiate revegetation of the bare soil more quickly than sites without the addition of seed bank material.

RESTORED VERNAL POOLS. Sites D and E included the removal of soil piles and/or debris during the restoration process for vernal pool habitats. This process produced exposed, barren substrates of both wetland and upland areas. At Site D, we took two approaches to revegetation: 1) some vernal pool habitat occurred contiguous to disturbed areas and, thus, might serve as a natural source for seed when

Fig. 11. COURSE-GRADE EXCAVATION OF THE CREATED POOLS. The scoop of a small Case Skiploader was used to form the general shape of each of the created pools.

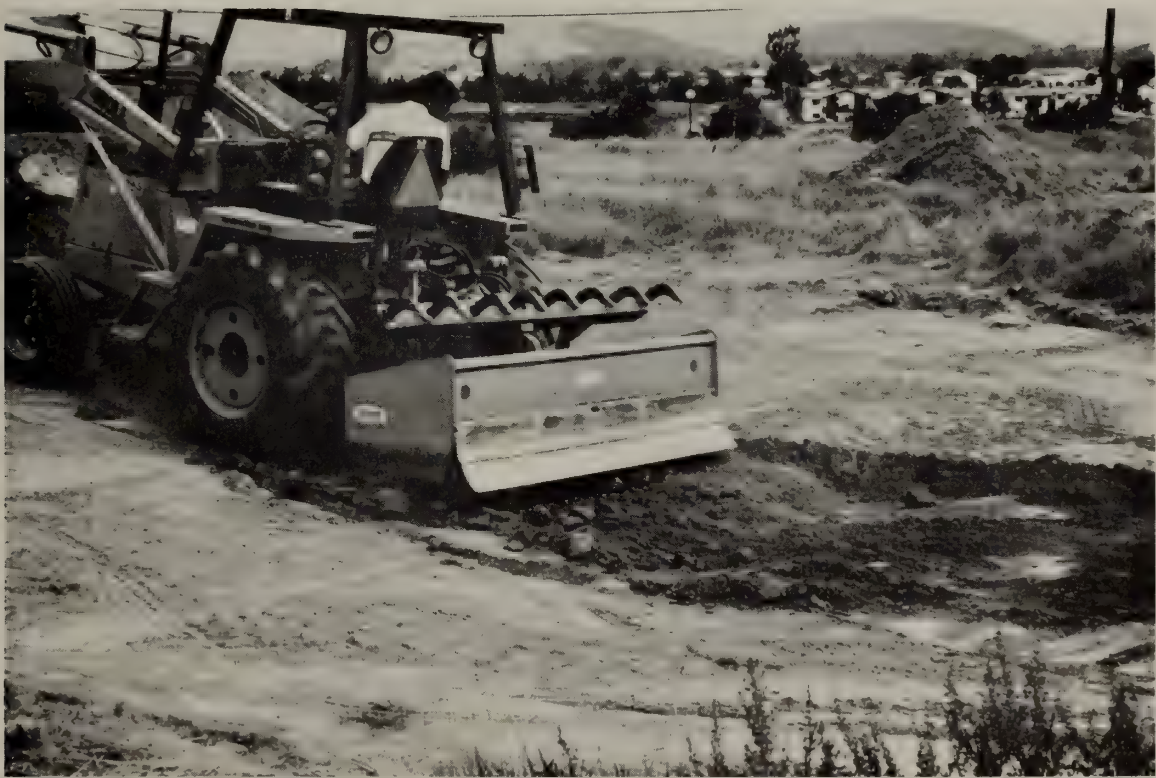

Fig. 12. FINE-GRADE EXCAVATION OF THE CREATED POOLS. The rear blade of a small Case Skiploader was used to construct the detailed contours of each of the created pools.

the restored area floods; and 2) seed bank material from vernal pools located on Ellwood Mesa, 2 km west of the Del Sol site, was used to inoculate some of the restored wetland habitat. The seed bank in the second approach was not dispersed in any quantifiable fashion and only included approximately five gallons (ca. 20 liters) of material. It was collected in Summer 1986 and dispersed the same day. No attempt was made to revegetate exposed upland habitats because we predicted that adjacent upland grassland sites would serve as a natural source for seeds. Collection of the vernal pool seed bank material is described in detail below (Revegetation Program--Created Vernal Pools). At Site E, exposed soil in wetland habitats also was not inoculated with seed bank material because vernal pool habitat was contiguous to restored areas and might serve as a natural source of seed when the pool is flooded and the natural and restored areas are linked hydrologically.

CREATED VERNAL POOLS. At Site F, where six depressions were created in an upland grassland setting, we implemented a formal, monitored, revegetation program to determine the effects of inoculating artificial vernal pool habitat with seed bank obtained from vernal pools of the region.

Shortly after excavation (see: METHODS--Construction Phase), Pritchett inoculated three randomly selected depressions with seed bank material obtained from combined material of two natural vernal pools. The donor pools are located on Ellwood Mesa and were selected for two reasons: 1) because the natural vernal pools at Del Sol Reserve are the only ones in public ownership and, thus, we chose not to subject them to additional disturbance by removing seed bank material; and 2) because they visually appear to support a higher diversity of native hydrophytes than many vernal pools in the region.

Within the donor pools, we have observed only one native plant species (<u>Psilocarphus brevissimus</u>) that apparently no longer occurred at the Del Sol site before transfer of seed bank material. However, several native vernal pool species (e.g., <u>Alopecuris howellii</u> and <u>Pilularia americana</u>) are not known from the group of donor pools at

Ellwood Mesa. We believe that our choice of donor pools from a local site other than the Del Sol Reserve did not substantially affect the floristic integrity of the vernal pools at the Reserve. In fact, if the entire Santa Barbara complex of vernal pools is considered a single unit, then the Del Sol Reserve could be used as a refugium for all restricted species, particularly those species (e.g., Eryngium armatum) that are supported locally by single pools or small groups of pools.

The inoculum from the donor pools was acquired by scraping, with a hand-held hoe, up to 1 cm of material from scattered areas within the natural pools (Fig. 13). About 1% of the donor pool's surface was scraped. The material was collected one day in late summer 1986 and dispersed the same day. The material included soil, various plant fragments, and, presumably, seeds of plants and eggs or cysts of invertebrate animals. A volume of 150 l (40 gal) of inoculum was collected and dispersed evenly among three of the randomly selected, created pools. The remaining three created pools were not inoculated so they could be compared with inoculated pools during the post-project monitoring program.

Post-project (Post-construction) Phase

Post-project Monitoring Program. To help evaluate the Construction Phase and Revegetation Program of the Del Sol Vernal Pools Enhancement Plan and to provide additional background information on the Del Sol Reserve, we designed and implemented a Post-project Monitoring Program that included studies of the flora, vegetation, and physical environment of both the Reserve and the Santa Barbara complex of vernal pools. Part One of this monitoring program was conducted from the first rainfall of the 1986-87 wet season (fall 1986) to the desiccation of vernal pool habitats (spring 1987) and the completion of the flowering season of Del Sol plants (summer 1987). Part Two was approved subsequent to the completion of Part One, and was designed to assess the functioning of vernal pools and growth of plants during the second year following the Construction Phase of the project.

Fig. 13. ACQUISITION OF SEED BANK FROM NATURAL VERNAL POOLS. The seed bank was obtained during summer 1986 from two donor pools at Ellwood Mesa. A garden hoe was used to scrape the surface of the natural pools. The seed bank and associated plant material were picked up with a dust pan and transported in a trash can to the site of the created pools. Three of the six created pools were inoculated with the seed bank.

POST-PROJECT TOPOGRAPHIC MAP. Condor Construction Company, assisted by Pritchett, surveyed the construction sites shortly after completion of the Construction Phase of the Enhancement Plan, and subsequently produced a post-project topographic map that is the same scale (1" = 30′) and comparable with the preproject map. This map includes the new topographic features produced during the enhancement, restoration, and creation aspects of the project, as well as prominent features also illustrated on the preproject map. To determine the percent area covered by wetland before and after the project, as illustrated on pre- and post-project maps, portions of the site mapped as wetland were cut and weighed and then compared with the weight of the map of the entire reserve.

INVENTORY OF THE FLORA. A thorough inventory of the Del Sol Reserve had not been conducted anytime previous to the proposed Enhancement Plan. Thus, the significance of the site in relation to other groups of vernal pools in the Santa Barbara region has not been estimated. Also, a reconstruction of the upland habitats prior to disturbance has not been estimated because no information on remaining native plants or vegetation units has been available for the specific site.

To provide an analysis of the significance of botanical resources at Del Sol Reserve, we examined existing lists and publications to construct a preliminary inventory of the species, and a plant collecting history of the vernal pool habitats of the region. Holly C. Forbes, a project subcontractor, conducted an inventory of all vascular plants at Del Sol Reserve that she observed during the project, from March to December 1987. This range of months permitted her to make numerous site visits during spring, summer, fall, and winter conditions. Thus, we consider her inventory to be authoritative. Voucher specimens for all observed species were prepared and are deposited at UCSB. Forbes also examined existing herbarium specimens at UCSB and the Santa Barbara Botanic Garden (SBBG, including the Herbarium of the Santa Barbara Museum of Natural History, SBM) to produce a list of specimens collected by other investigators and to determine if additional species not

observed by her had been collected previously. Her observations and collections plus those specimens from UCSB and SBBG were organized into an annotated catalogue (Appendix II).

To help determine the regional significance of vernal pool habitats at the Reserve, Forbes visited and collected voucher specimens from additional groups of vernal pools in the Santa Barbara region, including those at More Mesa, elsewhere in Isla Vista, at UCSB West Campus, and Ellwood Mesa. She also examined herbarium specimens at UCSB at SBBG and reviewed available reports and publications. The results of her regional inventory were organized into a second annotated catalogue (Appendix III).

MONITORING OF THE NATURAL, ENHANCED, RESTORED, AND CREATED VERNAL POOLS. To assess certain physical and biological aspects of vernal pools, transects were placed, in Spring 1987 and 1988, in a series of pools at the Del Sol site (Fig. 14) and in the two pools at Ellwood Mesa from which seed bank material was taken to inoculate the Del Sol pools. Twelve transects were located, one in each of 12 vernal pools, as enumerated in Table 4. Transects were created by placing permanent markers (rebar segments imbedded in the ground) to form a line bisecting the lowest point of each pool; the end points of the transect occurred in upland habitats beyond the vernal pool boundary. The distance between rebar segments differed among the pools depending on the size of the pool. In larger pools (E, G, N), the distance was every 5 m, in the Ellwood Mesa pools, the distance was 3 m, and in the created pools the distance was 1 m.

Hydrologic Conditions. To assess the hydrologic conditions of pools exposed to different treatments during the construction phase of the project, we determined the extent and duration of flooding by noting at various times the points along the transect that were inundated by water (Fig. 15). To note the highest and lowest water levels, we monitored the pools on days before and after rainfall. When these data are presented graphically, we can determine the duration of flooding for any point along the transect. However, for use with the data on plant

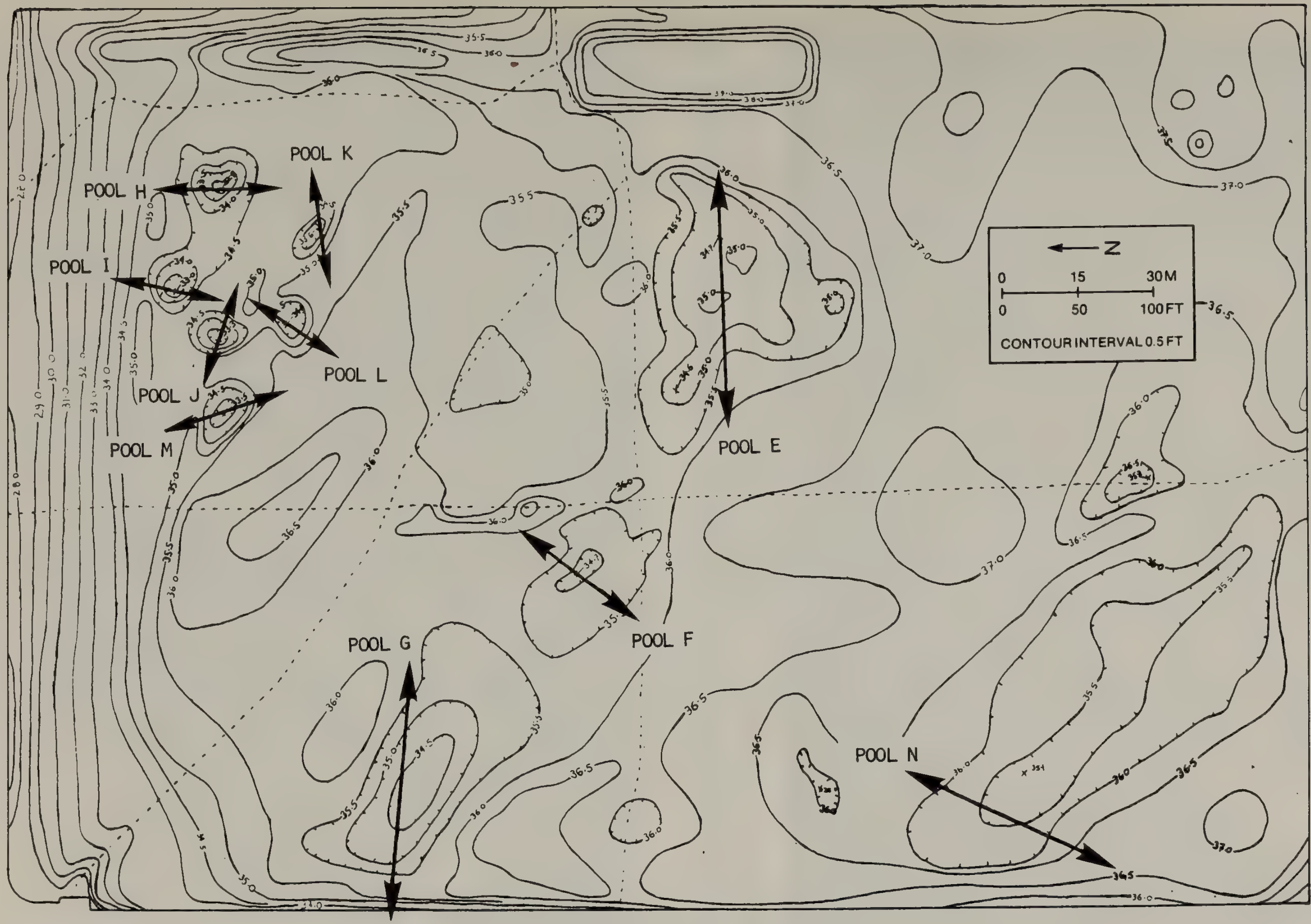

Fig. 14. LOCATIONS OF TRANSECTS (arrows) FOR POST-PROJECT MONITORING AT DEL SOL RESERVE.

abundances in the six created pools and two donor pools at Ellwood Mesa, Pritchett combined the hydrologic data into three classes of flooding: 1) areas flooded for one or more days (flooded); 2) areas within 1 m of flooding (low); and 3) areas further than 1 m from flooding (high). The results from monitoring in 1987 were compared among these eight pools. By combining data into three classes, we had more samples per class to evaluate mathematically than we would have had with individual samples. The three classes were selected because field observations suggested that they are different hydrologically and biologically.

Plant Cover In All Pools. Percent cover of all vascular plant species was determined along the same 12 transects used to assess the hydrologic conditions. In 1987, Pritchett sampled vegetation along the transects by using 0.5 m^2 quadrats placed at 2 m intervals (Fig. 16). In 1986, he used the same techniques to assess preproject conditions in Pool N and at the site of Pool H. In 1988, he sampled by using 1.0 m^2 quadrats placed at 1 m intervals in the smaller pools and at 2 m intervals in the bigger pools (Pools E, G, and N). Each transect spanned an entire pool and included upland and transitional habitats only within 2 m of the maximum water level observed earlier in the year. Cover was estimated for each species within an entire quadrat. The total cover for each species in each pool was calculated by finding the mean cover for each species along a transect. The total cover for each pool was estimated by adding the total cover of all species along a transect for each pool. The results were compared among all sampled pools. Frequency data for each species also were collected from quadrats by noting the number of cells in which a species occurred within each of the 100 cells per quadrat. These data are not presented or discussed here.

Species Abundance In Created And Natural Pools. To evaluate the revegetation program implemented at the created pool sites, Pritchett determined an Index of Abundance for vascular plant species sampled along the six transects in created pools at Del Sol Reserve and the two transects in donor pools on the Ellwood Mesa. The Index of Abundance is the relativized sum of the estimated cover for a species plus the

Fig. 15. TRANSECT FOR POST-PROJECT MONITORING PROGRAM. As shown here by Pool L, each pool in the Monitoring Program was marked with a transect of rebar poles. Hydrologic conditions were assessed by noting where the water level intercepted measured points along the transect. Plant abundances were sampled along the same transect.

Fig. 16. QUADRAT FOR POST-PROJECT MONITORING PROGRAM. Percent cover was estimated for each plant species occuring within the quadrat.

density of that species. Density is the total number of individuals of each species in twenty 10 x 10 cm cells that were selected randomly within each 0.5 m^2 quadrat. The Index of Abundance was calculated for each species in each quadrat.

Ten species were selected for the quantified analysis of plant abundances. They included: Psilocarphus brevissimus (Asteraceae) and Plagiobothrys undulatus (Boraginaceae), two annual species endemic to vernal pools in California; Eryngium vaseyi (Apiaceae), a perennial species endemic to vernal pools in California; Juncus bufonius (Juncaeae), an annual species with a cosmopolitan distribution; Eleocharis acicularis (Cyperaceae) and Lythrum hyssopifolia (Lythraceae), two perennial species with cosmopolitan distributions; Distichlis spicata (Poaceae), a perennial grass widespread in North America; Cotula coronopifolia (Asteraceae), an annual hydrophyte naturalized from South Africa; Erodium botrys (Geraniaceae), an annual species naturalized from the Mediterranean region; and Lolium multiflorum (Poaceae), an annual grass naturalized from Europe.

To increase the sample size used in the analysis, data from the quadrats of the six created pools and two natural pools were combined to form three treatments: 1) inoculated created pools; 2) uninoculated created pools; and 3) natural pools. Thus, for each species, an Index of Abundance was determined for three flooding classes in each of three pool treatments. The statistical analysis for each calculated abundance is two standard errors of the mean. The number of samples (N) for the nine possible evaluations for each species were as follows: natural pools high, 4; natural pools low, 1; natural pools flooded, 17; inoculated pools high, 18; inoculated pools low, 3; inoculated pools flooded, 12; uninoculated pools high, 10; uninoculated pools low, 5; and uninoculated pools flooded, 10. Data were displayed graphically to compare the results among species and among habitat treatment for each species.

Floras Of The Created And Natural Pools. In addition to the analysis of species abundances along transects in created and natural

pools, the floras of these pools were surveyed several times during spring and summer 1987. The occurrence of all species present in each pool was noted to determine the floristic similarity among inoculated created pools, uninoculated created pools, and natural pools. Voucher specimens were collected and deposited at the UCSB Herbarium. The data for each species were combined for all examples of each of the three treatments.

Faunas of the Created and Natural Pools. Although no study of invertebrate animals was required by the subcontract to UCSB, Pritchett sampled some of the pools for a preliminary evaluation of the invertebrate fauna. The enhanced pool (Pool N), an inoculated created pool (Pool M), an uninoculated created pool (Pool J), and a natural pool at Ellwood Mesa (Pool Q) were each sampled once at various times in 1987 and 1988. An aquarium dipnet (10 x 10 cm opening) was used to take several sweeps in each pool. Specimens were preserved in ethanol and identified at a later date. Occasional observations of vertebrate animal use of Del Sol vernal pools also were noted. In both the invertebrate and vertebrate cases, however, little quantifiable information presently exists to evaluate the importance of vernal pools for local fauna.

Mosquito Abatement Policies

With increasing development adjacent to wetlands, insect pests may become a problem. We identified conflicts between County policies (e.g. Santa Barbara County 1982) protecting vernal pools from potentially damaging effects of mosquito abatement practices and those policies that mandate protection from mosquito infestations. For example, the natural and degraded preproject pools at Del Sol were treated periodically with a mosquito larvicidal oil (a petroleum distillate) called Golden Bear 1356 (Stannard 1986). In addition, the hydrology of at least one pool (Pool N) was altered when a ditch was dug to partially drain the pool to reduce the potential for major mosquito infestations. Both of these abatement activities degrade vernal pools and are contrary to policies protecting wetlands in the Coastal Zone. Because the Enhancement Plan

includes 1) construction of berms to retain more water and 2) excavation of sites to increase wetland habitats, there will be a post-project potential for greater mosquito-breeding habitat. Because the coastal development permit for this project required a cooperative agreement for mosquito control, we worked with the IVRPD and the Goleta Valley Mosquito Abatement District to develop new policies regarding mosquito abatement practices at Del Sol Reserve that would provide protection for most vernal pool organisms.

Analysis and Publications

Analysis of the Del Sol Vernal Pools Enhancement Plan. Information gathered during the preproject and post-project studies was used to evaluate the overall effectiveness of the Enhancement Plan, and in particular to provide conclusions and recommendations concerning the enhancement, restoration, and creation of vernal pools in the Santa Barbara region. We also provide a statewide perspective on vernal pool management by comparing the results of this project with similar projects conducted elsewhere. Because this report contains results from only two years following the construction phase of the Plan, our conclusions and recommendations are intended to be preliminary. Further monitoring could provide additional insights into the effectiveness of the Enhancement Plan.

Publication of a Brochure and Guidebook. To fulfill Task 6 of the Enhancement Plan, we designed and published a layperson's interpretive brochure and a guidebook to vernal pools that focuses on the Del Sol site. We designed the brochure to include a map of the Reserve, summary of the Enhancement Plan activities, and an illustrated guide to some of the characteristic organisms. We designed the guidebook to include a more detailed explanation of vernal pools, Del Sol Reserve, and organisms that characterize the pools. These publications are part of the access and interpretive program associated with the Enhancement Plan and are intended to help develop public awareness of vernal pools and to gain further support for protection of these Environmentally Sensitive Habitats.

RESULTS AND DISCUSSION

Preproject Phase

Information presented and discussed in this section is organized into four major parts: 1) Preproject Phase; 2) Construction Phase; 3) Revegetation Phase; and 4) Post-Project Phase. This organization follows closely that used in the METHODS section of this report. The many subsections are listed hierarchically in the CONTENTS. Some redundancy in this type of presentation is unavoidable, but we hope it will be useful to those interested in the restorational purposes.

The preproject monitoring program for the Enhancement Plan focused on developing a description of the environmental setting of the regions and a description of particular attributes of the Del Sol Open Space and Vernal Pool Reserve. Such descriptions are essential to evaluate the status of the site before we manipulated the habitats and to interpret the ecological consequences of the manipulations.

Environmental Setting. The Reserve is located on a coastal mesa on the South Coast of Santa Barbara County, California, in the community of Isla Vista and adjacent to the Goleta Valley, approximately 1.6 miles (2.5 km) southwest of the Santa Barbara Municipal Airport (Figs. 4, 5). It is largely a natural site in an intensely developed urban setting. In spite of various environmental impacts, the Reserve continues to support regionally important wetland habitats and rare plant species.

CLIMATE. The South Coast of Santa Barbara County is characterized by a Mediterranean climate with mild, moist winters and moderately warm, generally rainless summers. Point Conception, which is located about 36 miles (58 km) west of UCSB, is considered a major climatic and biogeographic boundary in the Pacific Coast region because it marks the approximate boundary between the relatively cool, moist conditions to the north from warmer and drier conditions to the east and south (Barbour et al. 1975). Many plant species reach their northern or southern limits in the vicinity of Point Conception. The reserve is

located in the northwestern portion of the southern California Mediterranean climatic region.

Wind. This climate is influenced directly by the prevailing westerly transoceanic air currents. During winter months, however, the regional trend is for night and early morning offshore air movement driven by continental cooling. By afternoon the prevailing westerly winds and interior convection give rise to regional onshore winds, or occasionally to winds that blow parallel to the coast. During spring months the daytime wind patterns are similar to those of winter, but they are stronger. Summer months are characterized by stabilized weather, with calm morning conditions and light to moderate onshore air movement in the afternoon. During fall months, continental cooling generates offshore breezes at night that can be strong in large canyons such as those in the vicinity of Goleta and Santa Barbara.

Fog. Coastal fog and low clouds are an important characteristic of this region. The cool, moist air at low elevations along the coastline of southern California forms a temperature inversion layer, within which fog or low clouds form during the night and early morning hours. As the inversion layer is heated, it rises slowly during the day, and the fog evaporates. Low clouds develop more frequently during late spring and early summer mornings when warmer air comes in contact with cool ocean water. This overcast may be drawn varying distances inland, a process usually associated with seasonal warming of the interior. As ocean temperatures increase during the summer, the occurrence of fog and low clouds decreases.

Temperature. Temperature data have been recorded for Santa Barbara and the Santa Barbara Municipal Airport (Environmental Data Service 1974-1986). However, because of incomplete records at Santa Barbara and because of the proximity of the Airport to the Reserve, an evaluation of the information was made for only the Airport. These data reveal that during a ten year period prior to our project (1974-1983) the Santa Barbara region was characterized by the typically narrow seasonal range in temperature. This is illustrated by the average

temperature in the warmest month (August) that was only 14.1°F higher than the average temperature in the coolest month (December). Similar differences in average temperatures between warmest and coolest months were recorded (Weather Bureau 1930, 1952; Environmental Data Service 1973) during earlier periods of time for Santa Barbara (1894-1930, 13.4°F; 1931-1952, 15.2°F: 1941-1970, 14.3°F) and the Santa Barbara Municipal Airport (1931-1952, 13.8°F; 1941-1970, 14.1°F). Although some temperatures below freezing have been recorded, the average minimum temperature in the coldest month is several degrees above freezing. Similarly, although temperatures have been recorded over 100°F, the average maximum temperature was about 75°F and occurred in August. These mild conditions are due in large part to the maritime location.

Precipitation. Precipitation in the Santa Barbara region has a Mediterranean pattern: winter rain and summer drought. During a ten year period prior to our project (1974-1983), 89.8% of the average monthly precipitation fell during a six-month period (November through April). The average rainfall for this period was 18.79 inches (48.2 cm) compared with only 2.14 inches (5.5 cm) that occurred from May through October (Environmental Data Service 1974-1983). Similar patterns of rainfall have been recorded for earlier periods at Santa Barbara and the Santa Barbara Municipal Airport (Weather Bureau 1930, 1952; Environmental Data Service 1973). The average annual precipitation at Santa Barbara for the period 1867 to 1979 was 17.8 inches (45.6 cm); however, fluctuations in annual precipitation are considerable [e.g. 7.83 inches (19.9 cm) in 1975-1976, and 36.67 inches (93.1 cm) in 1982-1983]. Heavier precipitation, including some snow, is recorded for higher elevations in the Santa Ynez Mountains. Most rain-bearing storm systems come from the northwest in winter. Infrequent summer rains may occur from tropical air masses, but are generally of little consequence to plant growth.

In summary, botanical resources of the region are influenced by a regional climate characterized by temperatures that rarely dip below freezing and by variable, largely winter rainfall. Vernal pools are one

form of wetland occurring in this type of climate at sites where naturally occurring basins are underlain by impermeable substrates.

Geologic History. The geologic history of the South Coast of Santa Barbara County has been discussed in detail by Upson (1949, 1951), Dibblee (1966), and others. Our summary of this information covers approximately the last million years, which has included events that directly affected the formation of wetlands of the study area.

Early-Middle Pleistocene time was characterized by the continued rise of the Santa Ynez Mountains, subsequent erosion of uplifted material, and deposition of thick alluvial sediments onto the partially and unequally subsided coastal plain and shelf. Vertical displacement along parallel, E-W trending faults (e.g., More Ranch Fault) in the coastal plain resulted in the formation of coastal basins and mesas (e.g., Isla Vista Mesa). Today's drainage systems were established during this time (Dibblee 1966).

Late Pleistocene time included not only renewed uplift of the Santa Ynez Mountains and portions of the coastal plain, but also fluctuating water levels that were related to episodes of glaciation. During Sangamon interglacial time, for example, sea level was apparently higher than today, as evidenced by marine terrace deposits on mesas. These deposits interfinger landward with alluvium in basins and foothill canyons (Upson 1951, Lohmar et al. 1980). Subsequent sea level retreat during the Wisconsin glaciation (10,000-60,000 YBP) may have reached 250 ft lower than today's level (Upson 1949). This resulted in streams cutting deep channels into Sangamon deposits and in the formation of coastal canyons.

Holocene time has been characterized by continued erosion of uplifted areas, the deposition of alluvium in basins, and a continued but slight rise in sea level (Dibblee 1966). A post-Wisconsin rise in sea level caused the flooding of coastal canyons and basins, producing a series of estuaries sometime between 5000-7000 YBP (Lohmar et al. 1980). Devereux and Goleta Sloughs are examples of a flooded canyon and basin,

respectively. The rise in sea level, continued uplift of coastal mesas, and landward erosion of the coastal bluff has resulted in the present coastal configuration.

MORE RANCH FAULT. One major structural feature has influenced all mesas along the coast of the Goleta Valley. The east-west trending (ocean side up) More Ranch Fault occurs along the southern margin of Goleta Slough and bisects the east and west branches of historic Devereux Slough. The uplifted (ca. 30-100 ft elevation) coastal mesas (More, Campus, Isla Vista, and Ellwood) occur south of this fault. Upson (1951) estimated that as much as 2000 ft of vertical displacement has occurred along this fault. The present distribution of many vegetation types of the region are related directly to the topography that has formed as a result of movement along this fault. Examples include oak woodland/forest on north-facing slopes of the fault escarpment, vernal pools on the uplifted and flat-topped mesas, and estuarine and palustrine wetlands in flooded, down-faulted basins. All the naturally occurring vernal pools of the South Coast of Santa Barbara County occur on the mesas south of the More Ranch Fault or in "sag ponds" along the fault (e.g., on the Storke Estate property north of El Colegio Road).

ORIGIN OF VERNAL POOLS. Much has been written regarding the origin of vernal pools (see Zedler 1987 for review). In California, vernal pools occur in three major geomorphologic situations: coastal terraces; the broader alluvial valleys, especially the Central Valley; and ancient basaltic lava flows. Each region supporting vernal pools has a unique combination of soil and topographic features that contribute to the formation of them. Impermeable substrates can be formed by decomposed volcanic bedrock, cemented sands, sedimentary clay layers and caliche. Shallow depressions in which vernal pools occur generally develop in a flat or gently undulating topography with poor surface drainage, and have been described as resulting from various erosional processes.

In the Santa Barbara region, however, we have found through field work and examination of aerial photographs that many of the vernal pool complexes are associated with seasonally wet "seeps" and drainage troughs that have undulating surfaces and contain shallow depressions. This is apparently true for Del Sol Open Space and Vernal Pool Reserve, where seasonal seeps and drainages occurred but have been truncated by modern roads, sidewalks, and residential development. These drainages apparently flowed into Goleta and Devereux Sloughs. Thus, the present naturally occurring vernal pools at the Reserve are characterized by altered hydrological regimes and reduced connections between seeps and depressions in the drainages.

Land Use History. Native Americans lived in several relatively large settlements in the vicinity of Devereux and Goleta Slough for thousands of years prior to the founding of the Santa Barbara Mission by Spanish monks in 1786. Chumash use of the local natural resources were thorough but apparently rather benign. Although little recorded information on the biological resources is available for early periods of the Goleta Valley and vicinity, an 1871 map by the U.S. Coast Survey (Fig. 17) provides useful detail of the status of the land before extensive urbanization. Selected modern roads have been added to the original map and the Reserve is shown in bold outline. The Isla Vista Mesa was dominated by undifferentiated grassland, which apparently included various types of vernal wetlands such as seasonal seeps, drainages, and pools. A more detailed discussion of the historical events affecting Devereux and Goleta Sloughs and the vicinity of the Del Sol Reserve is included in Ferren et al. (1987).

Conditions of the study region at the end of the first quarter of the 20th Century are illustrated remarkably well in a 1928 aerial photograph (Fig. 18). Roads and agricultural activities are evident and the Reserve site appears in bold outline. Vernal wetlands appear as dark soil in various locations in Isla Vista, which at this time was a small village with scattered "ranches". There is no evidence of agricultural activities at the Reserve site in this photograph.

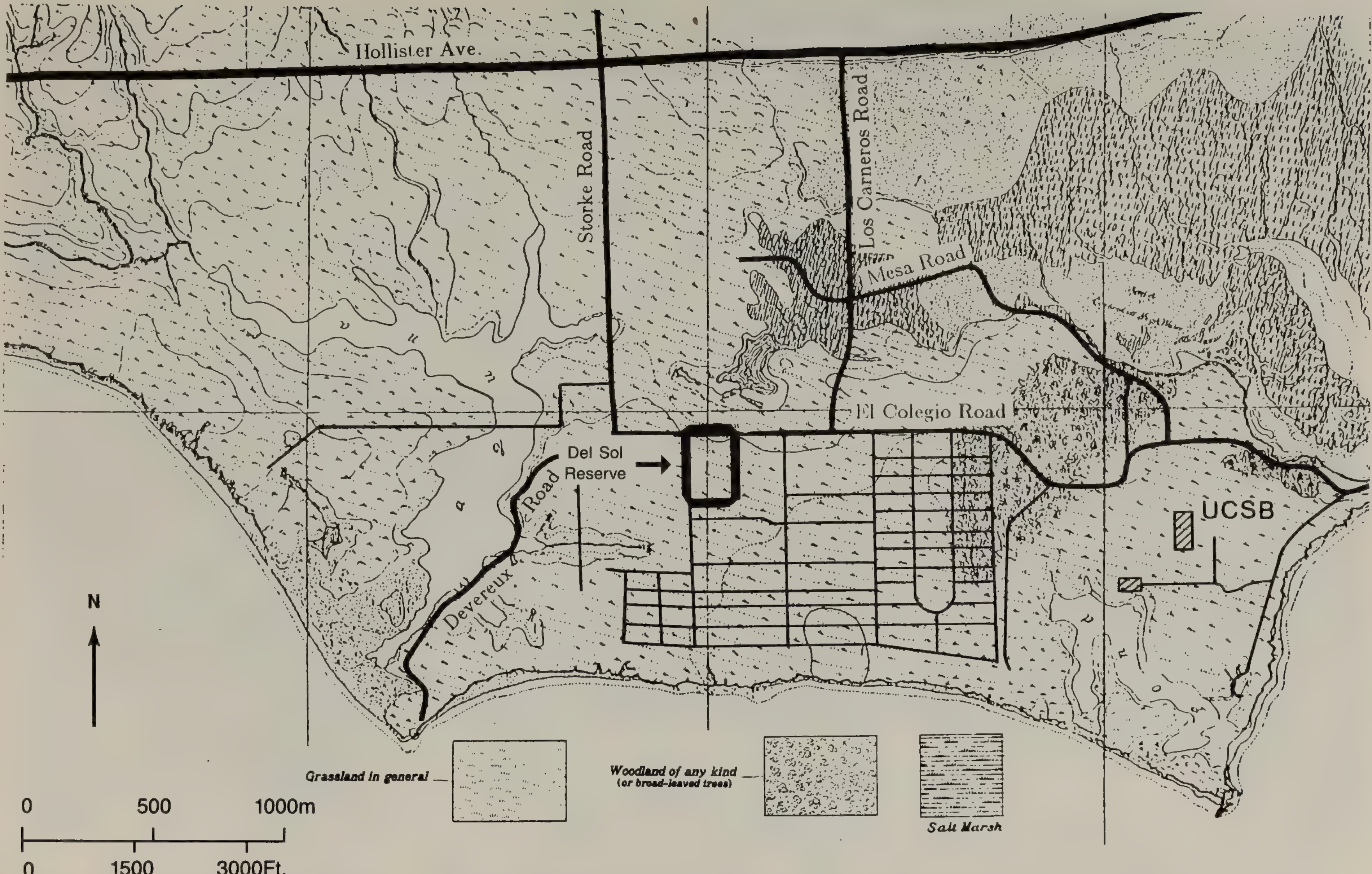

Fig. 17. DEL SOL RESERVE (outlined) AND VICINITY, 1871. The Del Sol site and most of Isla Vista were mapped as ''Grassland in General'' on this reproduction of the U.S. Coast Survey Map. Selected modern roads and two buildings at UCSB are shown for reference.

In a 1943 aerial photograph (Fig. 19), however, the majority of the Reserve site clearly was cultivated (light color). Three sites (dark color) apparently remained wetland and may not have been disturbed. These areas include vernal pools Sites A and E, and possibly portions of Sites B and D (see Fig. 6 for site locations). This photograph documents the obvious disturbance of most upland soils and possibly some shallowly flooded or saturated vernal wetland soils at the Reserve site. To the east of Isla Vista at the future location of the University of California, Santa Barbara (Fig. 19), grading and construction activities for a U.S. Marine Corps training base are evident. The base was founded in 1942 and marked the beginning of major urbanization trends in the vicinity of Del Sol Reserve.

Nearly two decades later in 1961 (Fig. 20) expanded residential development in Isla Vista and the construction of UCSB at the Marine Corps base had profound impacts over the amount and quality of open space and natural habitats in the region. The base was closed in 1945 and construction for UCSB began in the early 1950's. Expansion of residential development was associated with the development of the present UCSB campus and the subsequent need for housing. Some disturbance (foot paths and grading) at the Reserve site is evident in the aerial photograph of this year and encroachment of residential development had begun. Impacts to vernal wetlands in the region included fragmentation, infilling, dumping of refuse, and increased access.

By 1967 (Fig. 21) extensive urbanization of Isla Vista had occurred and the Reserve was one of the few undeveloped parcels containing vernal pools. These wetlands are visible in the 1967 aerial photograph and appear as connected troughs (dark areas), apparently the remnants of vernal seeps and drainages that have been truncated by roads. The Del Sol site was purchased in 1978 by the Isla Vista Recreation and Park District for preservation of the vernal pools.

Current conditions of the region are presented in a 1986 aerial photograph (Fig. 22), including the results of the "Construction Phase"

Fig. 18. DEL SOL RESERVE (outlined) AND VICINITY, 1928. Sparse agricultural development existed in the Isla Vista area, with apparently none occuring at the Del Sol site. Wetlands (vernal pools?) appear as darker areas, some of which are marked with arrows.

Fig. 19. DEL SOL RESERVE (outlined) AND VICINITY, 22 SEP 1943. Only moderate agricultural development occurred in Isla Vista, but nearly all of the Del Sol site was under cultivation. Disturbances from the new U.S. Marine Corps base are present at the area of UCSB campus. Portions of the site that are darker in color were not cultivated, and currently are wetlands and probably were wetlands in 1943 as well.

Fig. 20. DEL SOL RESERVE (outlined) AND VICINITY, 5 JUL 1961. Agricultural development has diminished, but urbanization of Isla Vista and UCSB has begun. Cultivation at the Del Sol site no longer occurs.

Fig. 21. DEL SOL RESERVE (outlined) AND VICINITY, 14 MAY 1967. Urbanization has nearly filled Isla Vista. Native and naturalized plants probably dominate the Del Sol site, but few if any trees or shrubs are apparent. Wetlands are visible as darker areas.

Fig. 22. DEL SOL RESERVE (outlined) AND VICINTIY, 31 OCT. 1986. Dense urbanization exists in Isla Vista. Vernal pool construction activities at the Del Sol site are shown as areas lighter in color, where the soil has been exposed. Pool N is visible in the SW portion, and trees and shrubs are apparent in the SE portion.

of the Del Sol Vernal Pool Enhancement Plan. At the Reserve (bold outline), habitat enhancements (e.g., narrow dams, on the west and south margins), restorations (e.g., excavated debris in the central eastern and northwestern areas) and newly created wetlands (e.g., excavated basins in the northeastern corner) are visible in the photograph. Foot paths clearly divide the Reserve into four nearly equal parts. Continued residential development has eliminated much of the remaining open space and native habitats in Isla Vista, other than wetlands associated with Devereux and Goleta Sloughs and occasional upland and vernal wetland sites such as Del Sol Reserve.

In Fig. 23, we compare the regional historic extent of vernal wetlands (excluding More Mesa) with the extent prior to the enhancement project. Based on aerial photography, numerous and occasionally extensive vernal wetlands occurred on Isla Vista (shown centrally) and Ellwood (shown to the west) Mesas before urbanization eliminated or reduced the size of most of these habitats, particularly those in Isla Vista. Recent residential development on UCSB West Campus eliminated a cluster of four pools on Isla Vista Mesa that are shown here (southwest central area). All remaining vernal wetlands are in private ownership except those at the Del Sol Reserve. The majority of the remaining pools, particularly those on Ellwood Mesa (western cluster), are threatened by current proposals for extensive residential development.

<u>Topographic and wetland maps</u>. Preproject topography (Fig. 24) and wetland/upland boundaries (Fig. 25) also were recorded for the Reserve. Preproject topography consisted of a gently undulated surface containing generally flat upland or mounded debris piles and shallow basins usually supporting wetland habitats. Although agricultural practices disturbed the soils for a portion of this century (see: Land use history) and a few sites were scarred by excavations or dumping, the overall topographic relief is probably close to a natural situation. The wetlands appear on many early aerial photographs (back to 1928) and are likely the remnants of natural vernal seeps, drainages and pools that historically were more widespread on the local coastal mesas prior to urbanization.

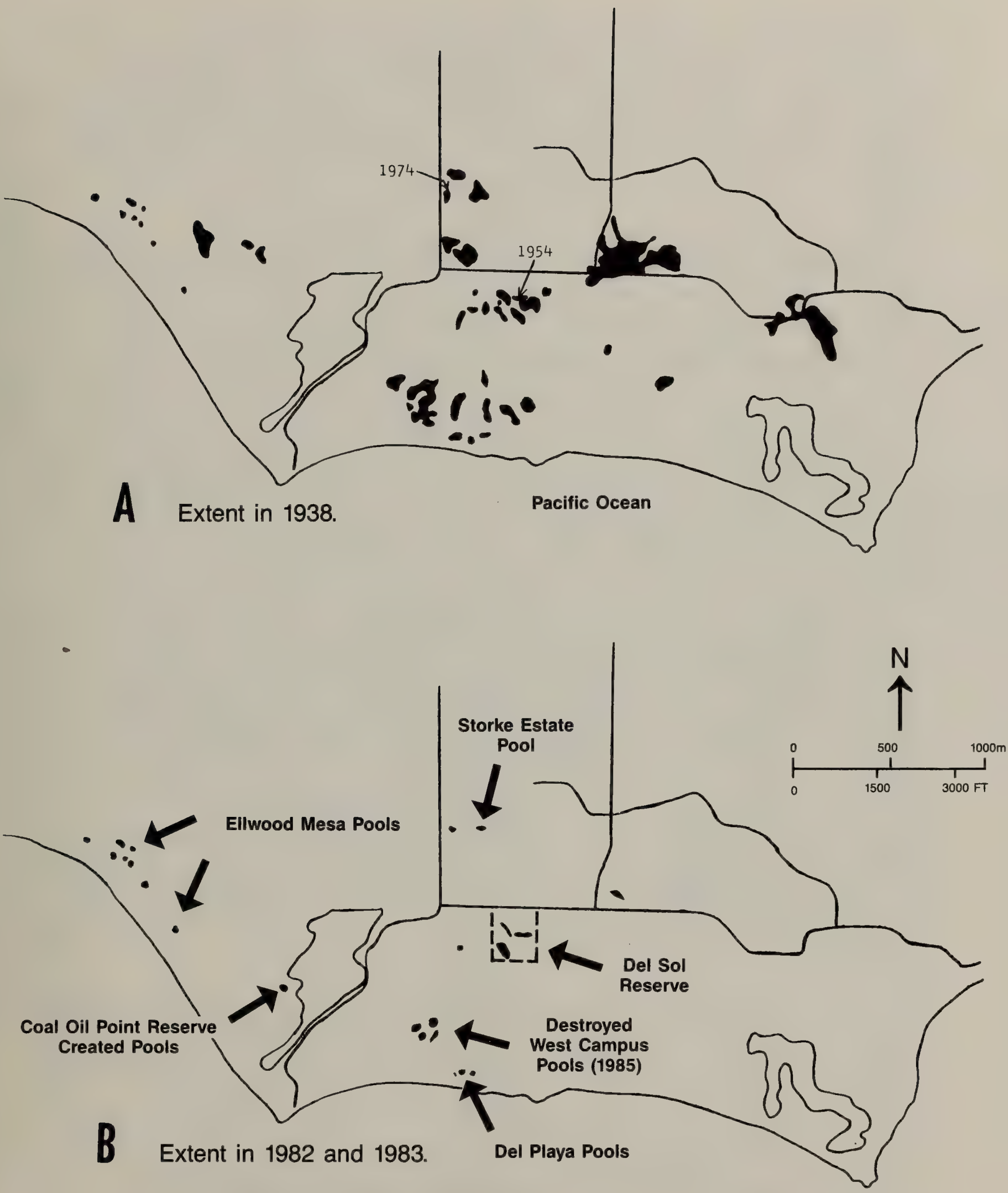

Fig. 23. HISTORIC EXTENT OF THE MAJORITY OF VERNAL POOLS AND RELATED WETLANDS (black polygons) IN THE ISLA VISTA AREA. A: Approximate extent as determined from 1938 aerial photograph. Two wetlands appearing after 1938 are marked by later dates. B: Approximate extent as determined from 1982 and 1983 photographs.

Following completion of the preproject topographic map (Fig. 24), we estimated the limits of wetland habitats based largely on the occurrence of vernal wetland vegetation. The mapped wetlands (Fig. 25) covered 15.9% of the site before the implementation of the enhancement plan.

Soils. Most of the Isla Vista Mesa and all of the Del Sol Reserve are covered with soil of the Concepcion Series (Shipman 1981). This soil occurs on low terraces in a narrow band parallel to the ocean. In some areas sandy windblown deposits occur on top of Concepcion soils.

Del Sol Reserve is covered with Concepcion fine sandy loam having largely 0-2% slopes, except along El Colegio Road where steeper slopes have been graded. Shipman (1981) described this particular unit as being strongly acidic and having a surface and subsurface layer of fine sandy loam to a depth of ca. 29 inches (0.74 m) and a subsoil clay layer to a depth of ca. 43 inches (1.09 m) followed by a subsoil clay loam to a depth exceeding 60 inches (1.52 m). This Concepcion unit has very low permeability due to the dense clay subsoil and is characterized by slow runoff. The water table is at a depth greater than 72 inches (1.83 m), but water does accumulate above the clay subsoil during the rain season.

The Concepcion Series is considered (Shipman 1981) to contain good top soil and can be cultivated with grasses and legumes, in particular dry farm grain or hay. The soils support a natural vegetation dominated by herbaceous species and shrubs.

The results of soil analysis for samples taken at nine locations at Del Sol Reserve (Fig. 6) are presented in Table 1. We found the surface and subsurface layer to be loams or sandy loams followed by an upper subsoil layer of clay, clay loam or loam, with another subsoil layer of sandy loam extending to at least 2.5 m. The subsoil layers with the greatest clay content were located on the northern half of the property (sample locations 1-4, Fig. 6); however, clay or clay loam layers may occur at the other sample locations (5-9) but could have been missed by the analysis because only layers every 0.5 m in each core were

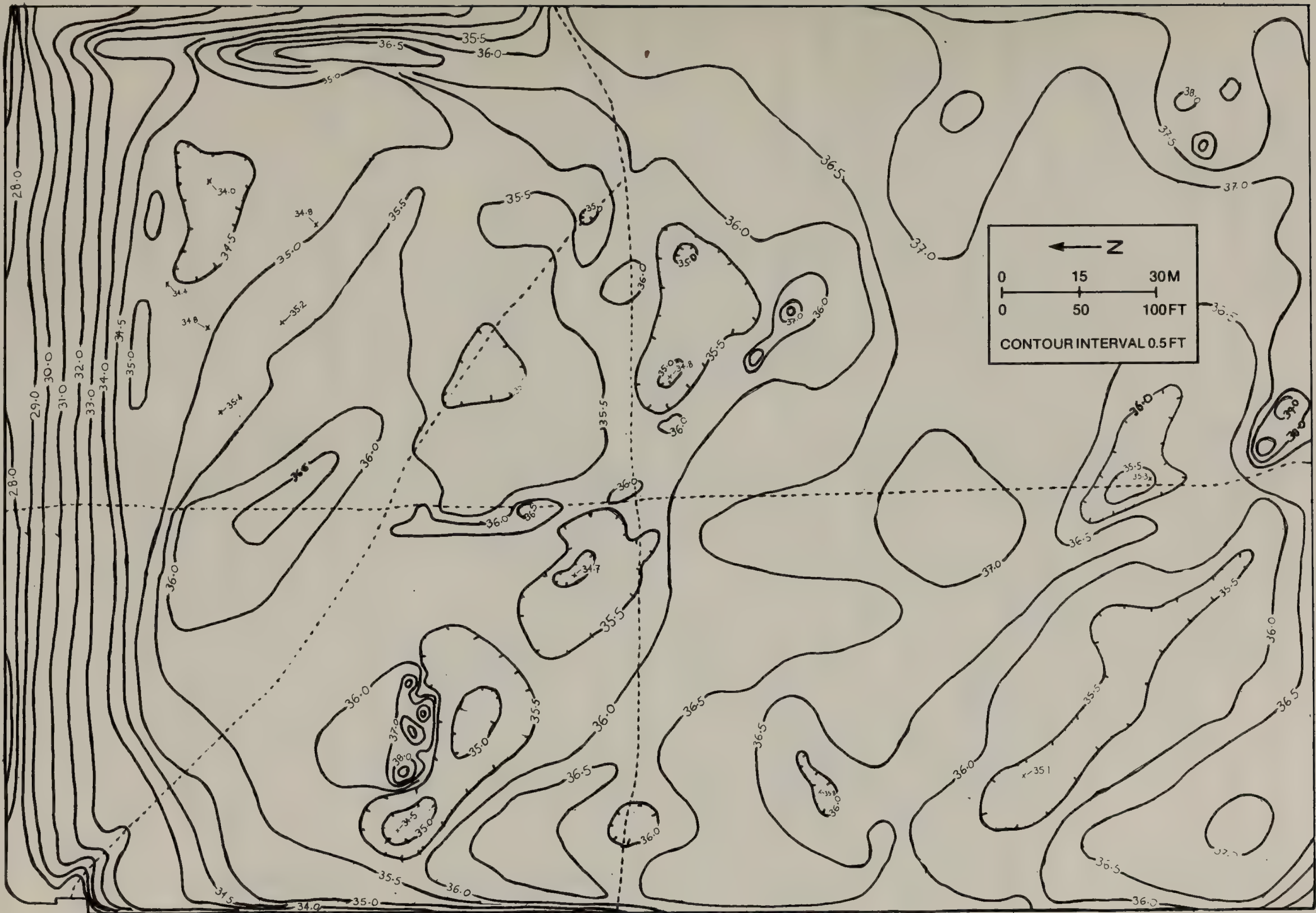

Fig. 24. PRE-PROJECT TOPOGRAPHIC MAP OF DEL SOL RESERVE.

evaluated. The clay and clay loam layers at sample locations 1-4 were at least 0.5-1.5 m and appeared to be thickest toward the northern end of the nearly level topography. This is where the created pools were constructed, and in at least one case the clay layer was exposed in the bottom of an excavated pool.

The demonstration of a subsoil layer containing clay and, hence, potentially with poor permeability, was an essential aspect of the preproject monitoring phase of the vernal pool creation part of this project. The presence of this layer virtually assured the retention of precipitation and potentially assured the development of a created environment similar to natural vernal pools of the Santa Barbara region. Our choice of this creation site adjacent to naturally occurring pools also contributed to the potential success of the project because of the probability of similar soil conditions occurring throughout the Reserve.

Vegetation and flora. A general preproject description of the historic and current vegetation and flora of the Isla Vista Mesa and Del Sol Reserve were essential to demonstrate the nature of the project area, the significance of the vernal pools, and the threatened aspects of the habitat and flora. This information was useful in developing the rationale for conservation, enhancement, and restoration of vernal pools and for presenting the nature of the Reserve before the Enhancement Plan was implemented.

The general region of the Isla Vista Mesa including portions of UCSB Main, Storke, and West Campuses, was characterized historically by grassland, vernal wetland, coastal scrub, and oak woodland/forest vegetation. This mosaic of vegetation apparently reflected the local differences in soil and topography, with oak trees occurring on the better, drained soils such as those on portions of Main Campus. Many of these trees were removed as a result of the whaling industry that occurred adjacent to Goleta Bay (Tompkins 1966); however, at least one grove occurred as late as 1871 and was illustrated on a Coast Survey Map of that year. The poor soils of the Reserve and vicinity apparently supported only herbaceous and shrubby vegetation (Shipman 1981).

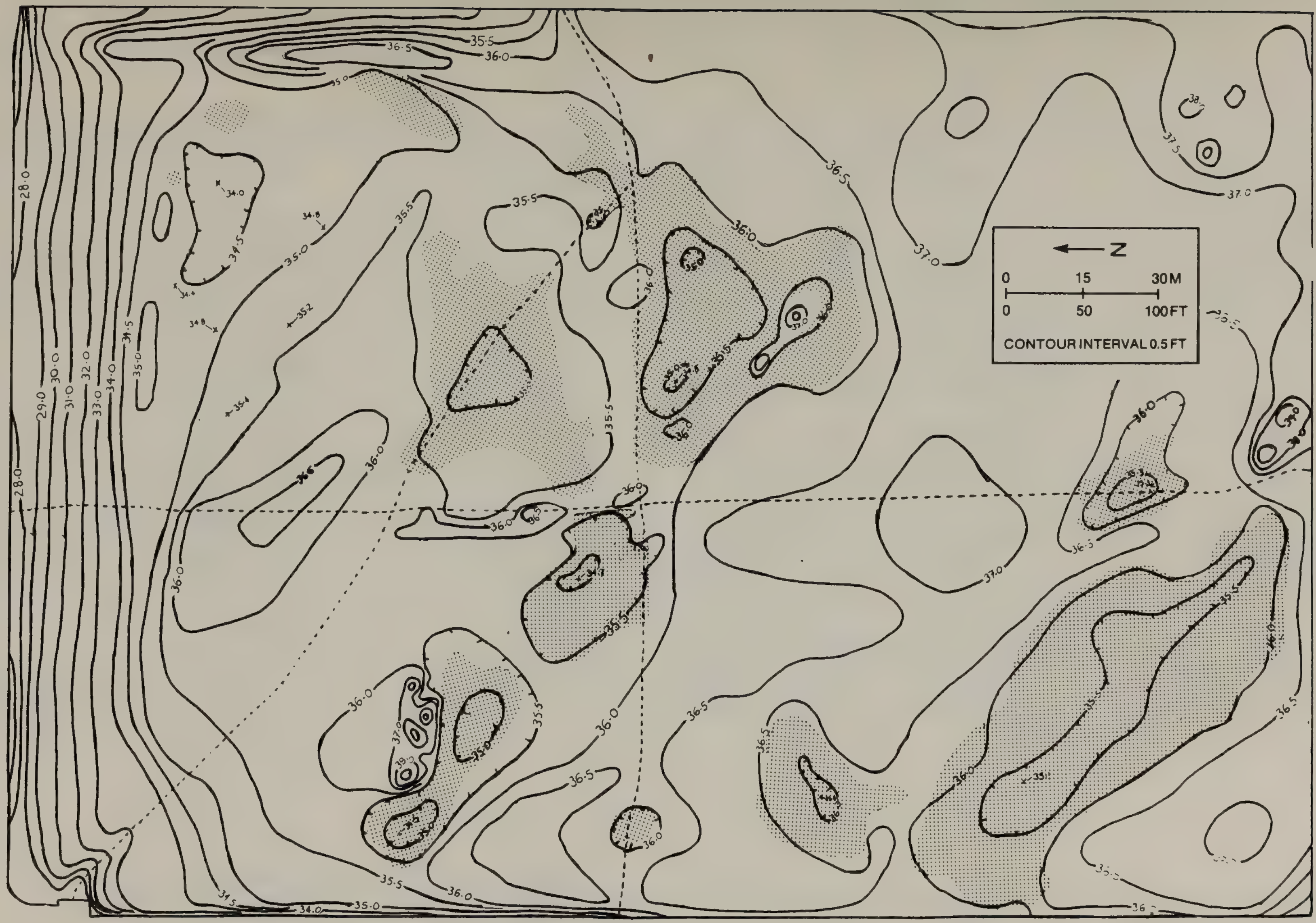

Fig. 25. PRE-PROJECT EXTENT OF WETLANDS AT DEL SOL RESERVE. The fraction of the site mapped as wetland (shaded areas) is 15.9%.

TABLE 1. SOIL MOISTURE, TEXTURE, AND PARTICLE SIZE DISTRIBUTION AT DEL SOL RESERVE. Locations of the samples are shown in Figure 6. Soils were analyzed by the hydrometer method, using the simplified clay and sand fractionation procedures described in Gee and Bauder (1986). Data from UCSB Soils Laboratory (1987).

Depth (m)	Moisture (%)	Texture	Particle Size(%) (Sand,Silt,Clay)
SAMPLE 1			
0.0	--	sandy loam	53, 40, 07
0.5	14.7	clay loam	24, 35, 41
1.0	11.15	clay loam	34, 34, 32
1.5	7.2	clay loam	33, 35, 32
2.0	--	sandy clay loam	52, 22, 24
2.5	2.8	sandy loam	64, 23, 13
3.0	7.0	sandy clay loam	54, 22, 24
SAMPLE 2			
0.0	--	sandy loam	53, 45, 02
0.5	12.9	clay	36, 24, 40
1.0	10.0	clay loam	40, 27, 33
1.5	5.8	clay loam	42, 31, 27
2.0	2.7	loam	40, 36, 24
2.5	5.7	sandy loam	64, 30, 06
3.0	4.8	sandy clay loam	59, 21, 20

Depth (m)	Moisture (%)	Texture	Particle Size(%) (Sand,Silt,Clay)
SAMPLE 3			
0.0	--	loam	39, 36, 25
0.5	13.3	clay loam	24, 38, 38
1.0	10.5	loam	44, 33, 23
1.5	6.9	loam	47, 31, 22
2.0	3.7	sandy clay loam	69, 07, 24
2.5	6.6	sandy loam	65, 16, 19
SAMPLE 4			
0.0	--	sandy loam	56, 38, 06
0.5	5.8	clay loam	21, 44, 35
1.0	7.7	loam	30, 44, 26
1.5	5.2	loam	33, 48, 18
2.0	5.9	loam	45, 39, 16
2.5	9.7	loam	42, 35, 23

TABLE 1. (Continued)

Depth (m)	Moisture (%)	Texture	Particle Size(%) (Sand,Silt,Clay)
SAMPLE 5			
0.0	--	loam	45, 35, 20
0.5	8.4	sandy loam	65, 23, 12
1.0	8.1	loam	50, 32, 18
1.5	8.1	sandy loam	60, 25, 15
2.0	13.8	sandy loam	58, 29, 13
2.5	2.7	sandy loam	60, 25, 15
SAMPLE 6			
0.0	--	sandy loam	55, 38, 07
0.5	6.6	loam	47, 30, 23
1.0	8.3	loam	47, 30, 23
1.5	4.0	sandy loam	62, 22, 16
2.0	7.0	sandy loam	62, 20, 18
2.5	3.9	sandy loam	80, 08, 12
SAMPLE 7			
0.0	--	sandy loam	60, 33, 07
0.5	5.1	loam	46, 30, 24
1.0	6.5	loam	46, 35, 19
1.5	9.0	loam	50, 30, 20
2.0	5.0	sandy loam	56, 25, 19
2.7	10.1	sandy loam	75, 15, 10

Depth (m)	Moisture (%)	Texture	Particle Size(%) (Sand,Silt,Clay)
SAMPLE 8			
0.0	--	loam	49, 42, 09
0.5	2.3	sandy loam	56, 34, 10
1.0	11.8	loam	39, 35, 26
1.5	12.1	sandy loam	61, 22, 17
2.0	8.0	sandy loam	56, 26, 18
2.5	7.4	sandy loam	56, 26, 18
SAMPLE 9			
0.0	--	loam	47, 38, 15
0.5	2.1	sandy loam	61, 28, 11
1.0	12.5	loam	46, 30, 24
1.5	11.3	loam	49, 34, 17
2.0	14.9	sandy loam	57, 30, 13
2.5	11.5	sandy loam	63, 22, 15

Before upland soils were cultivated and naturalized annual grasses and forbs invaded most disturbed sites, the grasslands apparently were dominated by native perennial grasses. Today, remnant native grasslands of the coastal mesas in the Santa Barbara region (e.g. More, Isla Vista, and Ellwood Mesas) include Stipa spp. (Needlegrass), Hordeum californicum (California Barley), Bromus carinatus (California Brome), Distichlis spicata (Salt Grass) and Elymus triticoides (Alkali Ryegrass) (Steele 1982, Thomson 1981, Whitmore 1983).

In its preproject condition, Del Sol Reserve was characterized by degraded vernal pools in topographically low areas and "Introduced Annual Grassland" and Baccharis pilularis (Coyote Brush) Scrub on the generally flat upland sites. The dominant naturalized annual grasses included Avena spp. (Wild Oat), Bromus diandrus (Ripgut Grass), B. hordeaceus (Soft Chess), Cynodon dactylon (Bermuda Grass), Lolium multiflorum (Italian Ryegrass), Hordeum spp. (Barley), and Vulpia bromoides (Fescue). Occasional native upland perennial grasses included only California Brome and Salt Grass. Numerous naturalized herbaceous species occurred throughout the grassland, scrubland, and debris pile sites including, for example, Foeniculum vulgare (Sweet Fennel), Carduus pycnocephalus (Italian Thistle), Sonchus spp. (Sow Thistle), Brassica spp. (Mustard), Raphanus sativus (Wild Radish), Convolvulus arvensis (Bindweed), Hypochoeris glabra (Smooth Cat's Ear), Melilotus spp. (Sweet Clover), Vicia spp. (Vetch), Erodium spp. (Filaree), Malva spp. (Cheeseweed), and Rumex angiocarpus (Sheep Sorrel).

In spite of the past disturbance of soils, the use of the Reserve for dumping refuse, and the preponderance of introduced species in the upland habitats, numerous native forbs persist at Del Sol Reserve and probably were associated with the native grassland vegetation that once dominated the mesa. Examples of the native upland forbs include: Asclepias fascicularis (Narrowleaf Milkweed), Ambrosia psilostachya var. californica (Western Ragweed), Gnaphalium californicum (Green Everlasting), Grindelia robusta (Gumplant), Hemizonia spp. (Tarweed), Heterotheca grandiflora (Telegraph Weed), Calystegia macrostegia ssp.

cyclostegia (Morning-glory), Eremocarpus setigerus (Dove Weed), Lupinus bicolor (Sky Lupine), and Sisyrinchium bellum (Blue-eyed grass).

The "natural" vernal pools of Del Sol Reserve apparently include impounded drainage troughs of seasonal seeps that once were common throughout the Isla Vista Mesa (see: RESULTS--Origin of Vernal Pools). Prior to the drainage of some pools by mosquito abatement ditches and the dumping of debris in others, the pools were often flooded with rain water for longer periods than in their degraded condition before the implementation of the Enhancement Plan.

A reconstruction of the species composition of the pools, based on personal observations, herbarium specimen labels, photographs, and published records, suggest that different zones of flooding support different species. For example, the seasonally saturated outer limits of the pools probably were characterized by a dense mixture of the native perennial grasses Hordeum californicum and Distichlis spicata, the perennial rush Juncus tenuis var. congestus (Yard Rush), and annual grasses such as the naturalized Lolium multiflorum. Native forbs of this outer zone included Brodiaea jolonesis (Dwarf Brodiaea), Grindelia robusta, and Stachys ajugoides (Hedge-nettle).

Wetland zones between the outer saturated margin and the deepest portions of the pools apparently had a mixture of grasses, sedges, and forbs, the great majority of which were native species. Grasses included Hordeum brachyantherum (Meadow Barley), Phalaris lemmonii (Lemmon's Canary-grass), and Alopecurus howellii (Pacific Foxtail); sedges included Eleocharis palustris and E. acicularis (Spikerushes); and locally common vernal pool forbs included Plagiobothrys undulatus (Popcorn Flower), Eryngium vaseyi (Coyote Thistle), and Lythrum hyssopifolia (Loosestrife).

Low areas among populations of the above species or in the bottoms of pools usually contained open, muddy substrates that supported the local mudflat flora of vernal pools. These species included Pilularia americana (Pillwort), Sagina occidentalis (Pearlwort), Callitriche

marginata (Water-starwort), Crassula aquatica (Water Stonecrop), Elatine brachysperma (Waterwort), and Juncus bufonius (Toad Rush). Many of these species also occur in the exposed margins of pools and along footpaths in pools where muddy substrates are exposed earlier in the season. Desiccated open substrates of late season vernal pools also support some species (e.g., Erygium vaseyi) restricted to other zones earlier in the season and support the summer/fall composite Hemizonia australis (Spikeweed).

Preproject knowledge of regionally rare species or threatened/endangered species provided some evidence of the special nature of the Santa Barbara pools. No vernal pool species are known to be endemic to the Santa Barbara region, but some species reach either northern distributional limits (e.g., Hemizonia australis) or southern distributional limits (e.g., Eryngium armatum, E. vaseyi) in the region. Other species of interest (e.g., Lasthenia conjugens) had not been observed for several decades. Preproject information on the flora contributed significantly to the acquisition of funds to implement an enhancement plan for the Del Sol Reserve. However, post-project inventories and analysis of the flora (see: RESULTS--Post-project Phase: Inventory of the Flora) provided additional important information on rare and endangered species, the significance of the Del Sol site, and the pools of the Santa Barbara region.

Construction Phase

Enhancement and restoration of vernal pools. Construction activities directly affecting the vernal pools occurred at sites A, D, E, and F as shown in Figure 6. The alteration to the topography at each pool is evident by comparing the pre-project topographic map (Fig. 24) with the post-project map (see Post-Project Monitoring Plan, Fig. 34). The total cost for project excavations and construction of berms, mounds, etc. was $13,250.00.

ENHANCEMENTS. **Cleanup.** The removal of trash was one type of habitat enhancement at Del Sol Reserve. Personnel from the California

Conservation Corps began the clean-up operation in late June 1986 by picking up small bits of rubbish that a single person could carry. In April 1987, staff from IVRPD, with the assistance of a UCSB fraternity, removed the last of the large refuse, which included items such as concrete blocks, plumbing pipes, a coil of chain-link fencing, a motorcycle frame, decaying furniture, and numerous bedframes. IVRPD maintains the clean-up operation by picking up trash at the Reserve every two months or so. Three trash receptacles (30-gallon cans) were installed for visitors' use at the elevated observational area.

Barricade. Further enhancements occurred at the reserve as a result of the barricade along the site's perimeter (see Fig. 34). The California Conservation Corps, and later IVRPD staff, installed wooden posts by digging holes and placing the posts in concrete. The posts on average are spaced 1.2 m apart and measure 0.5 m tall. They are green in color for a more natural appearance and cost about $4,000.00. They are very effective and exclude automobiles, which at various times have been used to dump refuse (e.g., the concrete blocks piled at Site E in Fig. 6), have been driven to the site to drain engine oil, and often cause severe degradation of the pools when deep wheel ruts form in wetland soils. Pedestrian and bicycle (and motorcycle?) traffic, however, can pass between the wooden posts for planned, unhampered access to the Reserve. A gap in the northeastern portion of the barricade exists to allow access for IVRPD vehicles when servicing the observational/picnic area, but the gap is usually closed with a chain and a padlock.

Dams. The dams at the two pools on Camino Corto (Sites A and E in Fig. 6, which respectively are Pools N and G in Fig. 14) provided a direct enhancement to these wetlands by altering their hydrology. Before construction of the dam, Pool G did not drain into the street as Pool N did, but the higher elevation at the western edge of this pool should increase the amount of flooding it receives by allowing water to back up towards the eastern portion. The entire area within the 35.5 ft contour may become inundated during years with high rainfall.

The dam at the southern portion of Pool N should enhance flooding like the dam at Pool G. Pool N did not drain here, but the elevated area should enhance flooding in other areas of the pool, especially during years of high rainfall. The dam at the western portion of Pool N raised the elevation about 0.5 ft, but more importantly it eliminated the mosquito abatement ditch (see Fig. 24) that allowed the pool to drain onto the street and provided favorable conditions for an increase in annual introduced grasses such as <u>Lolium multiflorum</u>. Before excavation of the ditch, this pool supported many native vernal pool species (Fig. 26); however, even after construction of the dam and subsequent filling of the ditch (Fig. 27), introduced grasses continue to dominate much of the habitat and a dense population of native vernal pool species has not returned. This result is probably due to 1) the lack of open substrate; 2) the persistence of <u>Lolium multiflorum</u>; and 3) the two years of low rainfall following construction of the dam.

RESTORATIONS. Restoration of Pools E and G resulted in a significant alteration of the topography of these wetlands. The hummocks and mounds formed by soil piles and concrete blocks in these two pools were removed and the debris was used to construct the observational area. Enough material was excavated from Pool E to make the lowest areas during pre-project conditions (Fig. 28) comparable with the highest areas during post-project conditions (Fig. 29).

Pool G was excavated to make two small basins (shown by the 35.0 ft contour) into a larger depression with a maximum depth below 34.5 ft. As the two restored pools (basins) were being graded, Ferren and Pritchett directed the equipment operators to construct minor depressions within the larger excavated basin of each pool. These depressions seldom were deep enough to be indicated on the topographic map, but they could provide a subtle environmental gradient along which the distributions and abundances of vernal pool species may vary (Zedler 1984). During years of limited rainfall, the depressions may form separate pools, but during years of average or above average rainfall they may fill and join to form one large pool.

Fig 26. ENHANCED POOL (POOL N) IN 1979. Before mosquito abatement ditches drained ponded water, this pool had a low abundance of naturalized grasses. Instead, native hydrophytes were conspicuous and included *Eleocharis palustris* (left foreground) and *Eryngium vaseyi* (right foreground). View is to the northwest.

Fig. 27. ENHANCED POOL (POOL N) IN 1987. After construction of the dam, this pool retains more water, but the dense population of naturalized grasses may persist for several years before diminishing. The barricade to motor vehicles is apparent on the right. View is to the south.

Fig 28. PRE-PROJECT CONDITIONS OF RESTORED POOL (POOL E). Before excavation, piles of soil, concrete, and other debris filled much of this pool, degrading its value as a wetland.

Fig. 29. POST-PROJECT CONDITIONS OF RESTORED POOL (POOL E). After excavation to remove debris, the pool's value as a wetland improved. Shown here is one of three deep areas that flood for longer periods of time than shallow areas.

Creation of vernal pools. Construction of the created pools resulted in six nearly uniform depressions (see Fig. 34) at the northeastern portion of the reserve (Fig. 30). Before excavation (Fig. 24), the area was flat except for a minor swale having a low point at 34.0 ft elevation and supporting introduced species. Pools H and I (designations of each pool shown in Fig. 14) were situated to take advantage of this pre-existing low area.

The average depth of each basin is about 45 cm as measured from the generally flat upland surrounding each basin. Basins (pools) H and I are the deepest of the six, whereas basins (pools) K and L are the shallowest. We found all six created basins are deeper than any of the natural basins at Del Sol Reserve (e.g., Pool F). This topography may have an effect on the flooding within the basins.

We designed the created pools to be deeper than the natural pools at the Reserve because the natural pools support much Lolium multiflorum, an invasive introduced grass that can become abundant in shallow wetlands. We also designed the created pools as deeper wetlands in order to provide a broad gradient of "hydrologic niches". Some species may occur more abundantly at areas within a pool that are flooded for prolonged periods, whereas other species may occur more abundantly at areas flooded for short periods. Zedler (1984, 1987) observed peaks in species abundances along a gradient of flooding for vernal pools in San Diego. Many of the same plants (e.g., Lythrum hyssopifolia and Psilocarphus brevissimus) in this study in San Diego also occur in Santa Barbara pools.

If the created pools were deep enough, we reasoned, then all local hydrologic niches would be present along the water duration gradient for a maximal diversity of vernal pool species. During years of high rainfall, some vernal pool species might be absent below a certain elevation, such as 33.0 ft, possibly because of high turbidity and/or anoxia resulting from prolonged inundation. During years with low rainfall, however, the same pools might support several vernal pool species below 33.0 ft elevation because the hydrologic niche was

appropriate for them at the time. Thus, the distribution of species in the created pools could be temporally and spatially dynamic according to rainfall patterns.

Additional Activities. The six small depressions for future plantings of oak trees (Site H in Fig. 6) were excavated as planned, but are not apparent on the post-project topographic map (Fig. 34). The depressions retain standing water only for a few days following one or more inches of rainfall. Coast Live Oaks (Quercus agrifolia) will be planted in the depressions by the IVRPD.

Revegetation Phase

The grading and excavation during the construction phase exposed the soil at some areas of the enhanced, restored, and created pools. Each of the three approaches to revegetation (i.e., stockpiling and redistribution of on-site seed bank; inoculation with seed bank acquired off-site; and no action to allow natural colonization) led to the establishment of plant cover, but the density and species composition varied among affected areas.

Enhanced Vernal Pools. The dams constructed at the margins of Pools N and G were the areas requiring revegetation. The "no-action" approach was used for the majority of the disturbed soil at all three dams and after two years resulted in moderate vegetative cover dominated by naturalized grasses. The dam at the eastern edge of Pool N, however, received a seed bank (the upper 10 cm of soil containing native and naturalized wetland and upland species) that was stockpiled nearby and redistributed on the side of the dam sloping into the pool (Fig. 31). The result was 100% cover on the slope, including some vernal pool species (e.g., Hordeum brachyantherum) on the lower part.

Restored Vernal Pools. The no-action approach to revegetation, which involved natural colonization from adjacent vegetated areas and growth from remnant seed bank, was the option used at the restored pools. Plant cover was established with no problem. A mixture of

Fig. 30. POST-PROJECT CONDITIONS OF CREATED POOL (POOL L). Two years after excavation and inoculation with a seed bank, this pool, photographed in May 1988, supports many species characteristic of natural vernal pools of the Santa Barbara area.

Fig. 31. REVEGETATION OF THE DAM AT ENHANCED POOL (POOL N). The side of the dam sloping towards the pool (on the right here) was overlain with topsoil obtained from the area where the dam was constructed. This side has 100% vegetative cover. The side of the dam sloping away from the pool (on the left here) was not overlain with topsoil and was left bare. It has only sparse vegetation.

native and naturalized upland and wetland species appeared in Pools E and G (Figs. 32 and 33).

In addition to the no action approach, however, a small amount of vernal pool seed bank material was introduced into Pool E. Only a few vernal pool plants arose from the introduced seed bank, probably because of the small amount of seed introduced and because of the competition with abundant naturalized grasses. Eleocharis acicularis, Eryngium vaseyi, and Elatine brachysperma were three vernal pool species that grew in low areas of the pool where naturalized weedy species did not persist. This pattern was repeated in 1986 and 1987.

Created Vernal Pools. The three created pools that were inoculated with seed bank material (Fig. 30) supported a much higher diversity and abundance of vernal pool species than the three uninoculated pools. A comparison among pools is provided below under RESULTS: Post-Project Monitoring Program. The impact caused by removing seed bank material at the donor pools on Ellwood Mesa was minor because 1) only about 1% of the pools' surface was scraped to obtain the material, and 2) the scattered locations of the scrapings within a pool allowed quick colonization by adjacent vernal pool species. Two years after acquiring the seed bank, Pritchett, who collected the material initially, noted that evidence of soil disturbance was barely perceptible.

Post-project (Post-construction) Phase

Post-Project Monitoring Program. Physical and biological conditions of vernal pools at Del Sol Reserve and nearby Ellwood Mesa were monitored for two years following the Construction Phase of the project. The results are presented below.

POST-PROJECT TOPOGRAPHIC MAP. A comparison of the pre-project map (Fig. 24) with the post-project map (Fig. 34) indicates how the construction activities altered the topography of Del Sol Reserve. An analysis of the elevational changes caused by grading in or near the

Fig. 32. RESTORED POOL (POOL E) SHORTLY AFTER EXCAVATION. No vegetation was present at graded and excavated areas.

Fig. 33. RESTORED POOL (POOL E) TWO YEARS AFTER EXCAVATION. The open soil, a result of excavation, was colonized mostly by weedy naturalized species, but a few native hydrophytes also occured. The overall density of vegetation should continue to increase for several more years. Propagules of native hydrophytes came from both remnant seedbank in wetland soil left at the site and from minor amounts of seedbank added after excavation.

enhanced, restored, or created pools is discussed earlier in this report (see RESULTS - Construction Phase).

The topographic maps provide a basis for current and future monitoring and management at Del Sol Reserve. For instance, the post-project extent of wetland (Fig. 35) is 18.7% of the total area, a net increase of 2.8% above the pre-project extent of wetland (Fig. 25). A gain of only 2.8% may seem low for such an ambitious project, but the most important consideration lies in the quality of wetland gained, not the quantity. Furthermore, the greatest focus of the construction phase of the project was enhancement and restoration of existing wetlands, not the creation of new habitats. The following results include data regarding the resources of the Reserve and data regarding how the quality of vernal pools has been affected by the project.

INVENTORY OF THE FLORA. Results of the inventory of vascular plants of Del Sol Reserve are presented in an annotated catalogue of the species (Appendix II) and the results of the inventory of all groups of vernal pools in the Santa Barbara region are presented in a second catalogue (Appendix III). Both catalogues also include citations of specimens of local vernal pool species that are housed in the herbaria of the University of California, Santa Barbara (UCSB), and the Santa Barbara Botanic Garden (SBBG), which includes the Herbarium of the Santa Barbara Museum of Natural History (SBM). Additional information was obtained from publications (e.g., Smith 1976) reports (e.g., Thomson 1981, Office of the Chancellor 1984) and manuscripts (e.g., Baley and Ferren 1983, Whitmore 1983). This section is an extension of the discussion of the flora included in this report under RESULTS--Preproject Phase.

A total of 102 species have been collected or reported from Del Sol Reserve (Appendix II), including 42 native species and 60 naturalized (and planted?) species. The Asteraceae (22 species) and Poaceae (20 species) are the largest families. An additional five species (<u>Deschampsia danthonioides</u>, <u>Lasthenia conjugens</u>, <u>Lasthenia fremontii</u>, <u>Plantago bigelovii</u>, and <u>Sagina occidentalis</u>) have been

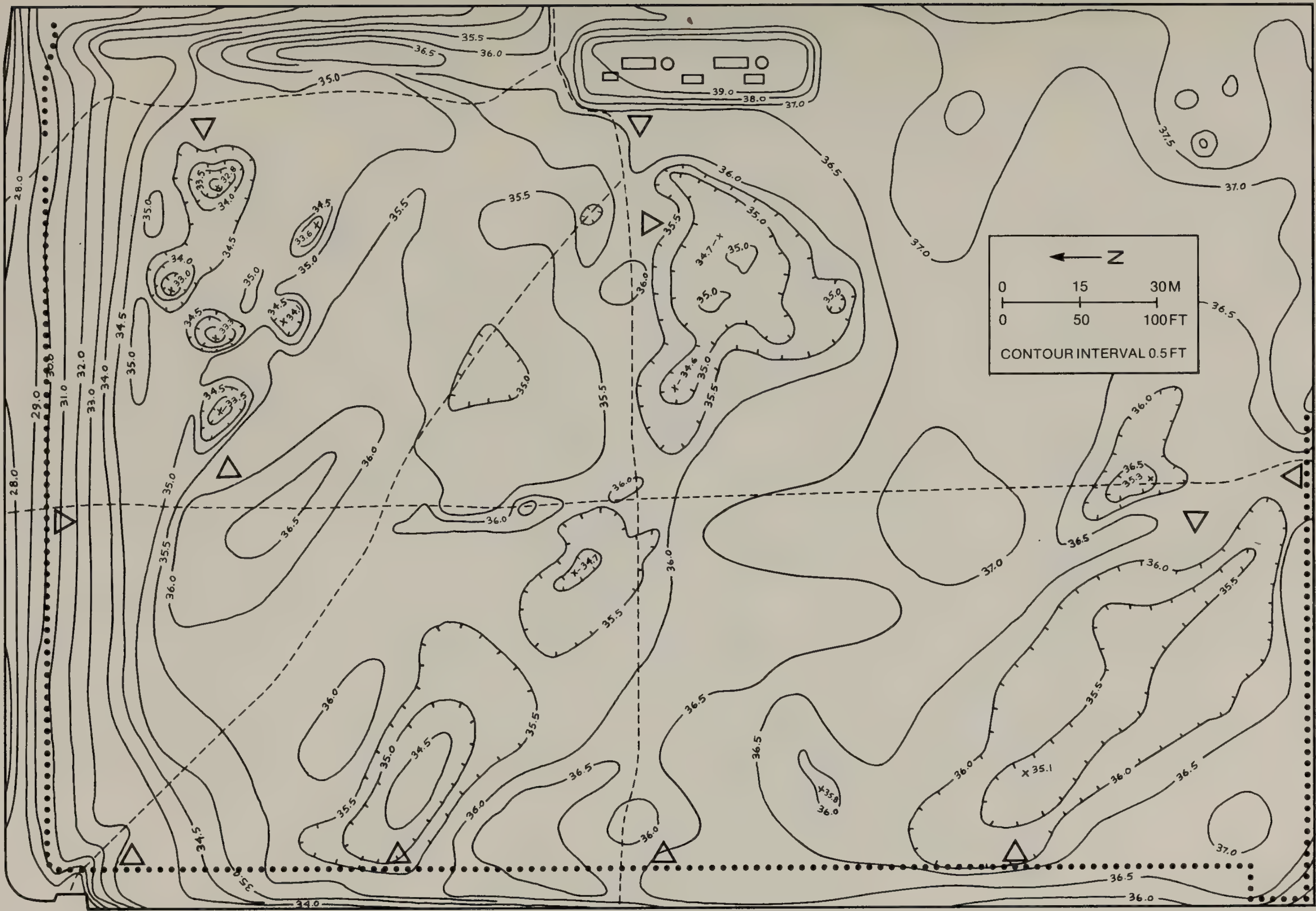

Fig. 34. POST-PROJECT TOPOGRAPHIC MAP OF DEL SOL RESERVE. Benches are shown at the eastern-central section, interpretive signs are indicated by triangles, and the barricade of posts is marked as dots on the perimeter.

collected from the Isla Vista Mesa, but their specimen labels generally contain no specific information about the part of Isla Vista in which they were collected. Although they may have occurred at the Reserve, we have not observed these species in vernal pools in the Santa Barbara region. The most recent collections of all but _P_. _bigelovii_ were made before 1961, prior to or during the extensive urbanization of the Isla Vista Mesa. _Plantago_ _bigelovii_ was last observed in the Santa Barbara region on the West Campus portion of Isla Vista Mesa in 1981. The site was destroyed.

Del Sol Reserve supports most of the endemic or vernal pool restricted species found in the Santa Barbara region (Table 2). However, in addition to those species that appear to have been extirpated from the region, three additional species do not occur presently at the Reserve. These latter species (_Boisduvalia_ _glabella_, _Eryngium_ _armatum_, _Gnaphalium_ _palustre_) occur in other groups of vernal pools in the Santa Barbara region. Of those regionally extirpated or absent species, two (_Boisduvalia_ _glabella_, _Plantago_ _bigelovii_) are generally restricted to the shallow, moist "vernal flats" that are not present at Del Sol Reserve, but occur in lightly grazed pastures where naturalized grasses are reduced to a minimum and disturbance by horses has maintained some open substrate.

In the Santa Barbara region, only one species, _Pilularia_ _americana_ (Pillwort), is restricted presently to the vernal pools at Del Sol Reserve. It apparently was collected in the Goleta area (presumably Isla Vista) as early as 1879 (Smith 1976), and all subsequent collections from Santa Barbara County apparently have come from Del Sol Reserve. Today the population appears to be restricted to the largest vernal pool at the site (enhanced Pool N), where it was once more common before a mosquito abatement ditch apparently caused annual draining to reduce the extent and duration of flooding.

The majority of vernal pool species in the Santa Barbara region are those aquatic plants either with a widespread occurrence or a more limited western occurrence, but which are restricted to vernal pools

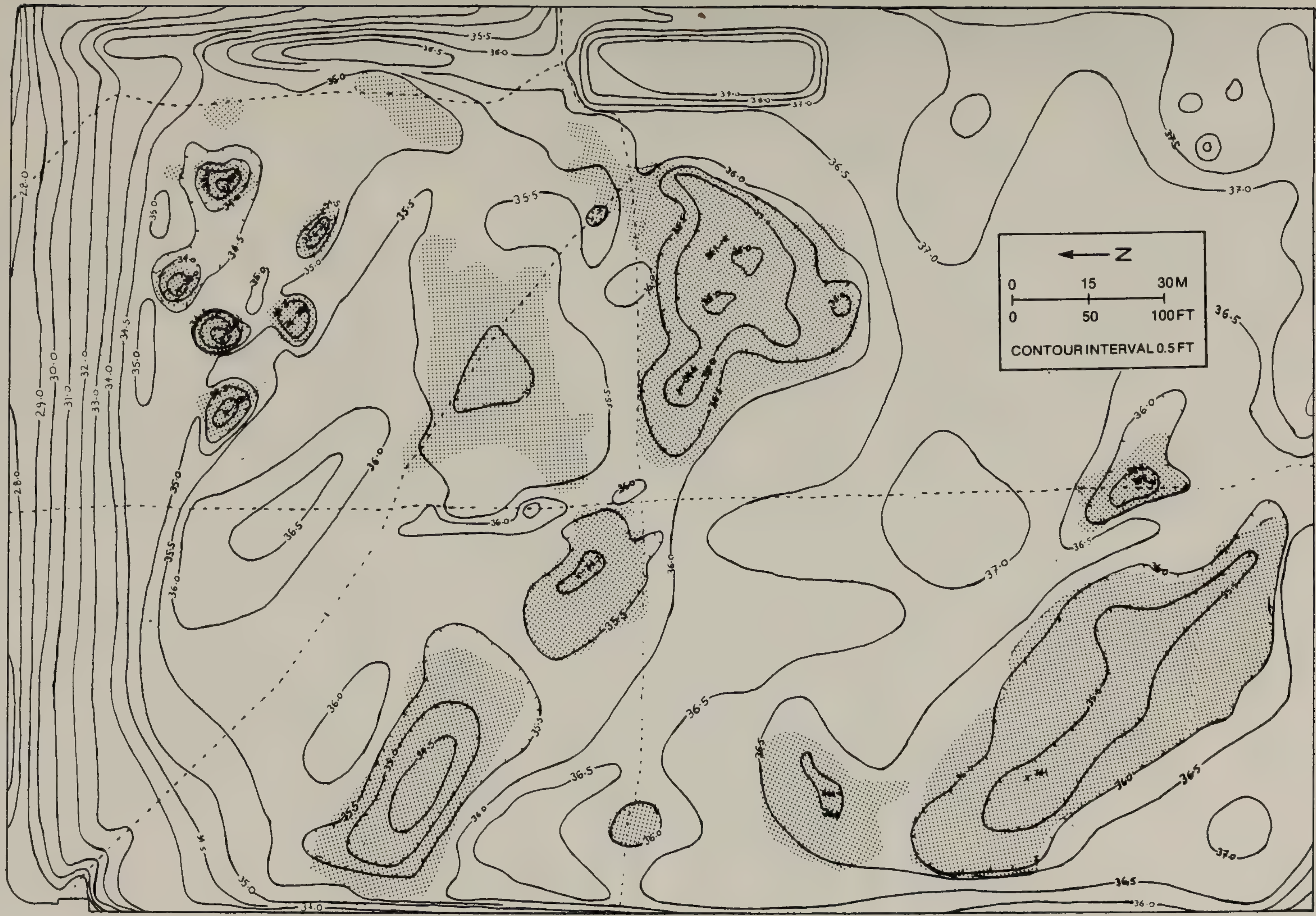

Fig. 35. POST-PROJECT EXTENT OF WETLANDS. The fraction of the site mapped as wetland (shaded areas) is 18.7%.

when they occur in this region (Table 2). The regionally rare Pilularia americana is a noteworthy example. Six local vernal pool species, however, are apparently endemic to this habitat in California or adjacent areas. In the Santa Barbara region, these endemics include species common to many local vernal pools (Callitriche marginata, Eryngium vaseyi, Plagiobothrys undulatus, Psilocarphus brevissimus) and apparently once included regionally extirpated species (Lasthenia conjugens and Lasthenia fremontii).

The majority of the endemic and restricted species also are uncommon to rare in the Santa Barbara region (Table 2). This is probably a result of not only the limited amount of suitable habitat in the region or throughout their range, but also the loss of habitat here and elsewhere due to urbanization and agricultural development that has destroyed the majority of the vernal pool habitat in California (Zedler 1987). Two species of special interest collected from the region have been listed by the California Native Plant Society (Smith and Berg 1988). These include the regionally extirpated species Lasthenia conjugens ("Contra Costa Goldfields", which is endemic to California and endangered throughout its range) and Hemizonia australis ("Southern Tarplant", listed as needing more information to determine status, although many historic occurrences may be extirpated). Lasthenia conjugens also is a federal candidate (Category 2) endangered or threatened species (USFWS 1985).

As noted previously (see: RESULTS--Environmental Setting) Del Sol Reserve occurs south of Point Conception in a transition between the northern (and central) biogeographic region and the southern biogeographic region of California. Many plant species reach their northern or southern limits of range in the vicinity of Point Conception, and various special habitats in the transitional area often support populations of species found more characteristically in northern or southern California. In the vernal pools and adjacent grasslands of the Santa Barbara region, seven species reach or once reached their limits of distribution. Centaurium floribundum, Eryngium armatum, Eryngium vaseyi and Hemizonia increscens ssp. increscens presently reach

Table 2. NATIVE PLANT SPECIES OF VERNAL POOLS IN THE SANTA BARBARA REGION.
Included here are plants from the Del Sol Reserve as well as from other groups of pools in the region. Endemic species are those thought to occur only in vernal pools in California and adjacent areas. Restricted species are those that generally occur only in vernal pools when found in the Santa Barbara region. Widespread species occur widely in western North America, North America, or elsewhere. Uncommon to rare species are those found only in a few sites in the Santa Barbara region, generally in vernal pools. Northern or southern species are those that reach their limits of distribution in the Santa Barbara region. Listed species are those of special concern as identified by the California Native Plant Society (Smith and Berg 1988) or listed (C2) by the U.S. Fish and Wildlife Service (1985). √ = species present; EW = Ellwood Mesa; IV = Isla Vista Mesa in addition to Del Sol Reserve; MM = More Mesa; WC = UCSB West Campus; extirpated = may have been eliminated from the Santa Barbara region; [date] = last known collection from the Santa Barbara region; N = northern limit of distribution and S = southern limit of distribution occurs in the Santa Barbara region.

	Del Sol Reserve	Other Santa Barbara Sites	Endemic Species	Restricted Species	Widespread Species	Uncommon to Rare Species	Southern or Northern Species	Listed Species
Alopecurus howellii	√	MM		√		√		
Boisduvalia glabella	-	EM, WC		√		√		
Brodiaea jolonensis	√	IV, MM				√		
Callitriche marginata	√	EM, IV	√?	√		√		
Centaurium floribundum	-	EM		√?		√	S	
Centunculus minimus	√	EM, IV		√	√	√		
Crassula aquatica	√	EM, IV, MM, WC		√	√	√		
Cyperus eragrostis	-	EM			√			
Deschampsia danthonioides	-	IV		√		extirpated? [1960]		
Distichlis spicata	√	IV, EM			√			
Elatine brachysperma	√	EM, IV, WC		√	√	√		
Eleocharis acicularis	√	EM, MM, IV, WC		√	√	√		
Eleocharis palustris	√	EM, IV, MM, WC			√			
Eryngium armatum	-	IV		√		√	S	
Eryngium vaseyi	√	EM, IV, MM, WC	√	√		√	S	
Hemizonia australis	√	EM, IV, WC		?		√	N	CNPS-3
Gnaphalium palustre	-	EM, IV, WC			√			
Hordeum brachyantherum	√	EM, IV, WC		√	√	√		
Juncus bufonius	√	EM, IV, MM, WC			√			
Juncus phaeocephalus	√	IV						
Juncus tenuis	√	IV, MM		√	√	√		
Lasthenia conjugens	-	IV	√	√		extirpated? [1950]	S	CNPS-1b;C2
Lasthenia fremontii	-	IV	√	√		extirpated? [1950]	S	
Lythrum hyssopifolia	√	EM, IV, MM, WC			√			
Phalaris lemmonii	√	EM, IV, MM		√		√		
Pilularia americana	√	-		√	√	√		
Plagiobothrys undulatus	√	EM, IV, MM, WC	√	√		√		
Plantago bigelovii	-	WC		√		extirpated? [1980]		
Psilocarphus brevissimus	√	EM, IV, WC	√	√		√		
Sagina occidentalis	-	IV			√			
Stachys ajugoides	√	EM, WC		√		√		
Veronica peregrina	√	EM, WC		√	√	√		

their southern limits in the region, whereas Lasthenia conjugens and Lasthenia fremontii historically reached their southern limits here. Hemizonia australis is the only species that reaches its northern limits in the region. Hemizonia increscens ssp. increscens is the only one that reaches its limit of distribution at Del Sol Reserve, where it occurs along paths, in grassland, and on the margins of vernal pools.

MONITORING OF THE NATURAL, ENHANCED, RESTORED, AND CREATED VERNAL POOLS. Ten pools at Del Sol Reserve (Fig. 14) and two natural pools at Ellwood Mesa (Fig. 5) were monitored for two years. The data were gathered along permanent transects bisecting each pool.

Hydrologic Conditions. The extent and duration of flooding in vernal pools and wetlands in general are functions of hydrologic inputs and outputs. Inputs include rainfall, coastal fog, surface flow, and subsurface flow, whereas outputs include soil moisture storage, surface flow, subsurface flow, evaporation, and transpiration (Linsley et al. 1982).

Rainfall and evaporation can be regarded as constant at all the pools because of geographic proximity. Other hydrologic inputs and outputs, however, can vary considerably. Transpiration was probably neglible in the pools, but should be greater in pools supporting more vegetation.

Rainfall is overwhelmingly the most important input. A comparison of rainfall events (Table 3) with hydrologic conditions in the 12 monitored pools (Figs. 36 and 37) reveals a strong relationship between flooding and the amount of precipitation. All of the "blips" along the vertical axes in Figures 36 and 37 correlate with recorded rainfall in Table 2. An outstanding example of the relationship between rainfall and flooding is apparent on Day 65 (Fig. 36), a time when 92 mm of precipitation fell during three consecutive days in March 1987 (Table 3). This was enough rainfall to connect two isolated bodies of water in Pool E, to initiate flooding in Pools P, Q, N, and F, and to

TABLE 3. RAINFALL AT DEL SOL RESERVE 1986-87 AND 1987-88. Dates of rainfall events, monthly totals, and monthly means for 10 years (1973 to 1982) are shown. Data are from rain gauge in Isla Vista or Santa Barbara Airport (NOAA 1986, 1987, 1988).

Days Since 1 Jan 87	Date	Rainfall Amount mm	inches
	24 Sep 86	38	1.5
	Sept Total	38	1.5
	10-yr Mean	18	0.7
	Oct Total	0	0.0
	10-yr Mean	15	0.6
	17 Nov 86	3	0.1
	Nov Total	18	0.1
	10-yr Mean	33	1.3
	05 Dec 86	20	0.8
	Dec Total	20	0.8
	10-yr Mean	48	1.9
3	03 Jan 87	3	0.7
4	04 Jan 87	11	0.5
6	06 Jan 87	16	0.6
	Jan Total	30	1.8
	10-yr Mean	119	4.7
40	09 Feb 87	19	0.8
44	13 Feb 87	33	1.3
46	15 Feb 87	5	0.2
	Feb Total	58	2.3
	10-yr Mean	114	4.5
63	04 Mar 87	9	0.4
64	15 Mar 87	75	2.9
65	06 Mar 87	8	0.3
72	13 Mar 87	4	0.1
73	14 Mar 87	3	0.1
80	21 Mar 87	14	0.5
	Mar Total	109	4.3
	10-yr Mean	119	4.7

Days Since 23 Oct 87	Date	Rainfall Amount mm	inches
1	24 Oct 87	42	1.7
5	28 Oct 87	6	0.3
8	31 Oct 87	6	0.3
	Oct Total	58	2.3
	10-yr Mean	15	0.6
13	05 Nov 87	19	0.8
25	17 Nov 87	3	0.1
	Nov Total	23	0.9
	10-yr Mean	33	1.3
42	04 Dec 87	34	1.3
44	06 Dec 87	7	0.3
54	16 Dec 87	15	0.9
67	29 Dec 87	25	1.0
	Dec Total	89	3.5
	10-yr Mean	48	1.9
74	05 Jan 88	30	1.2
87	18 Jan 88	30	1.2
	Jan Total	61	2.4
	10-yr Mean	119	4.7
102	02 Feb 88	4	0.1
128	28 Feb 88	28	1.1
	Feb Total	56	1.2
	10-yr Mean	114	4.5
	Mar Total	0	0.0
	10-yr Mean	119	4.7
155	15 Apr 88	25	1.0
163	23 Apr 88	51	2.0
	Apr Total	76	3.0
	10-yr Mean	30	1.2

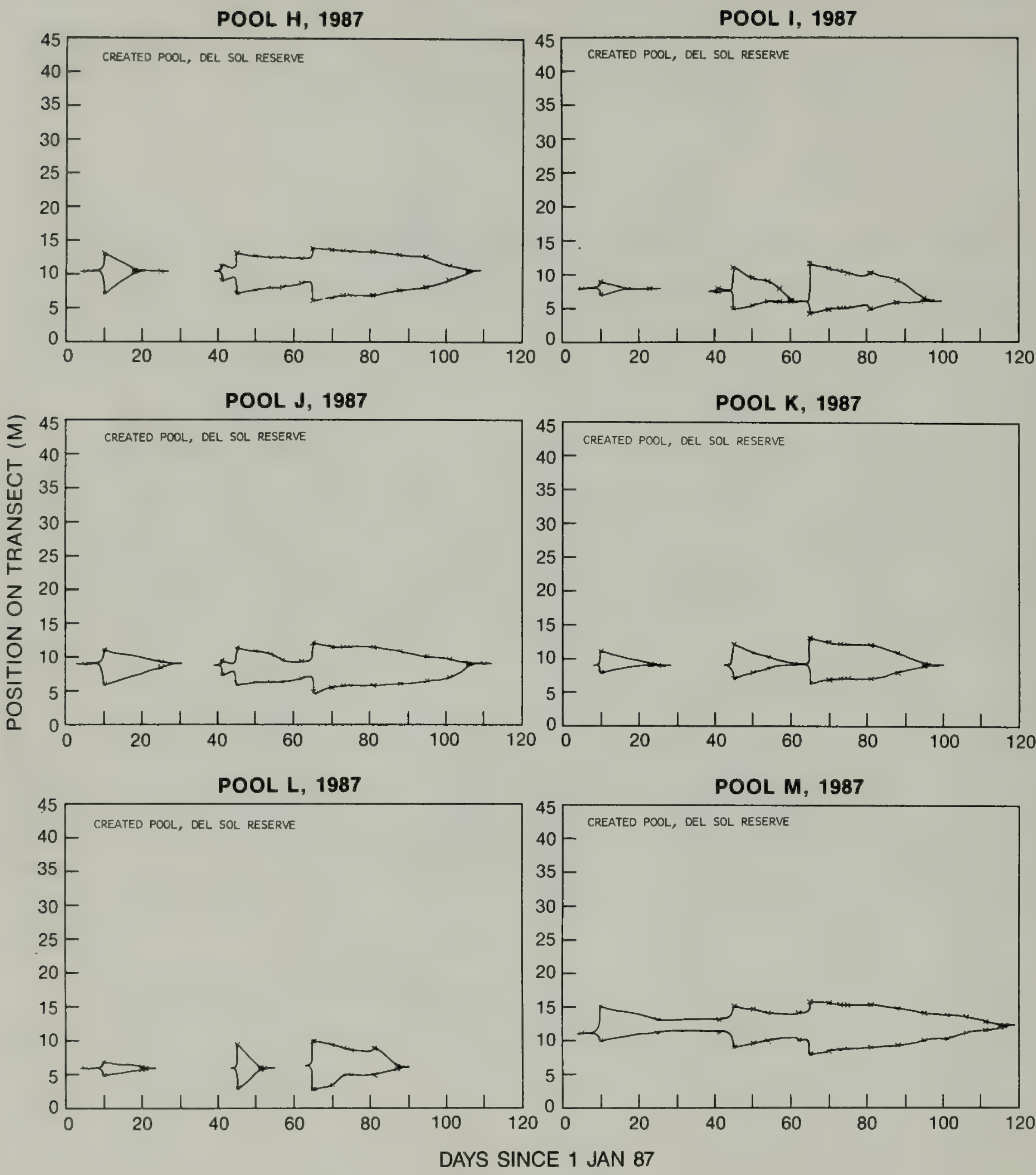

Fig. 36. HYDROLOGIC CONDITIONS IN 1987 OF VERNAL POOLS AT DEL SOL RESERVE AND ELLWOOD MESA. The area within each polygon indicates the extent and duration of flooding within each pool. Locations of pools are shown in Figure 14. Manipulation of pools (e.g., restored or created) is noted for each.

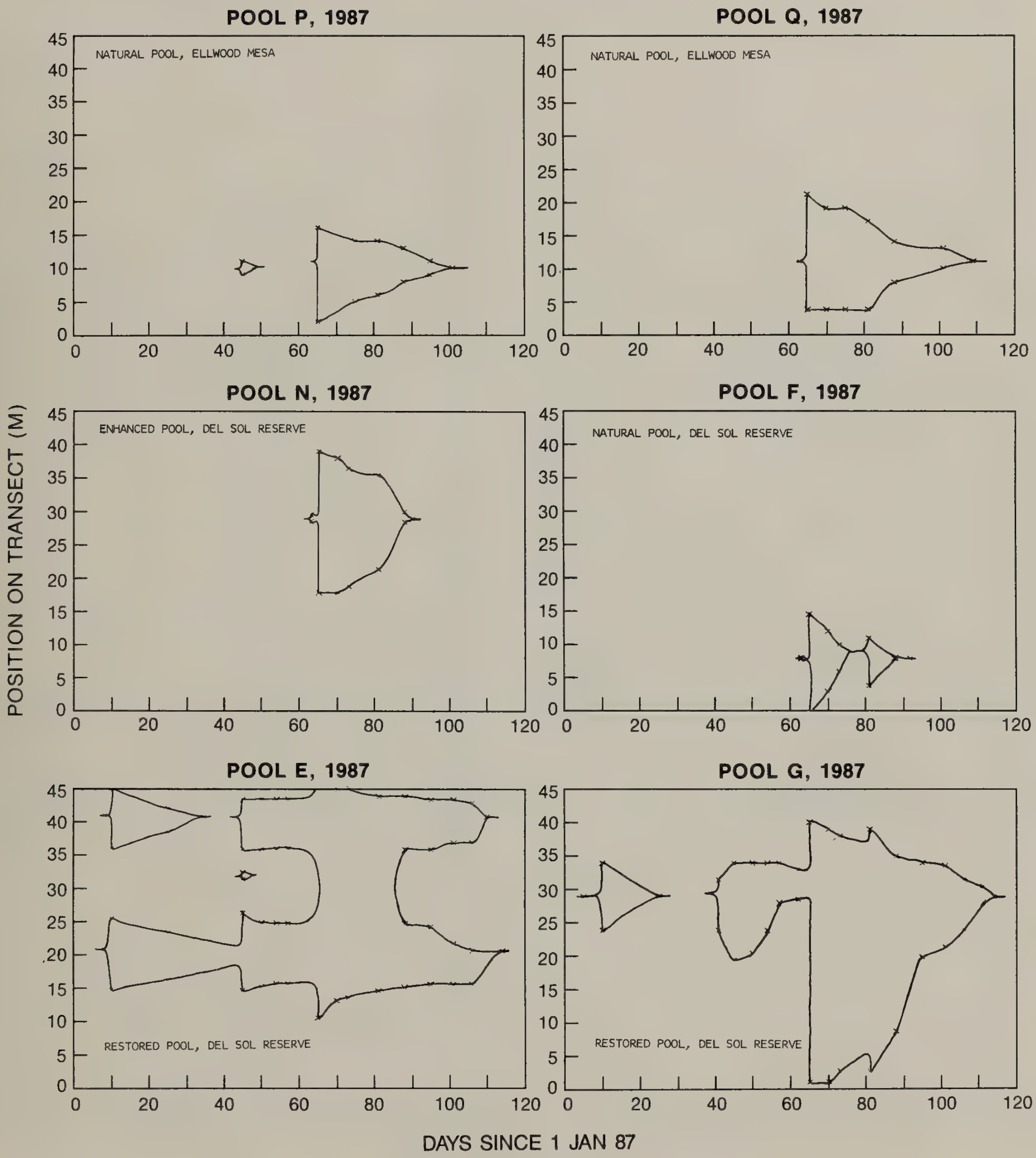

Fig. 36. Continued.

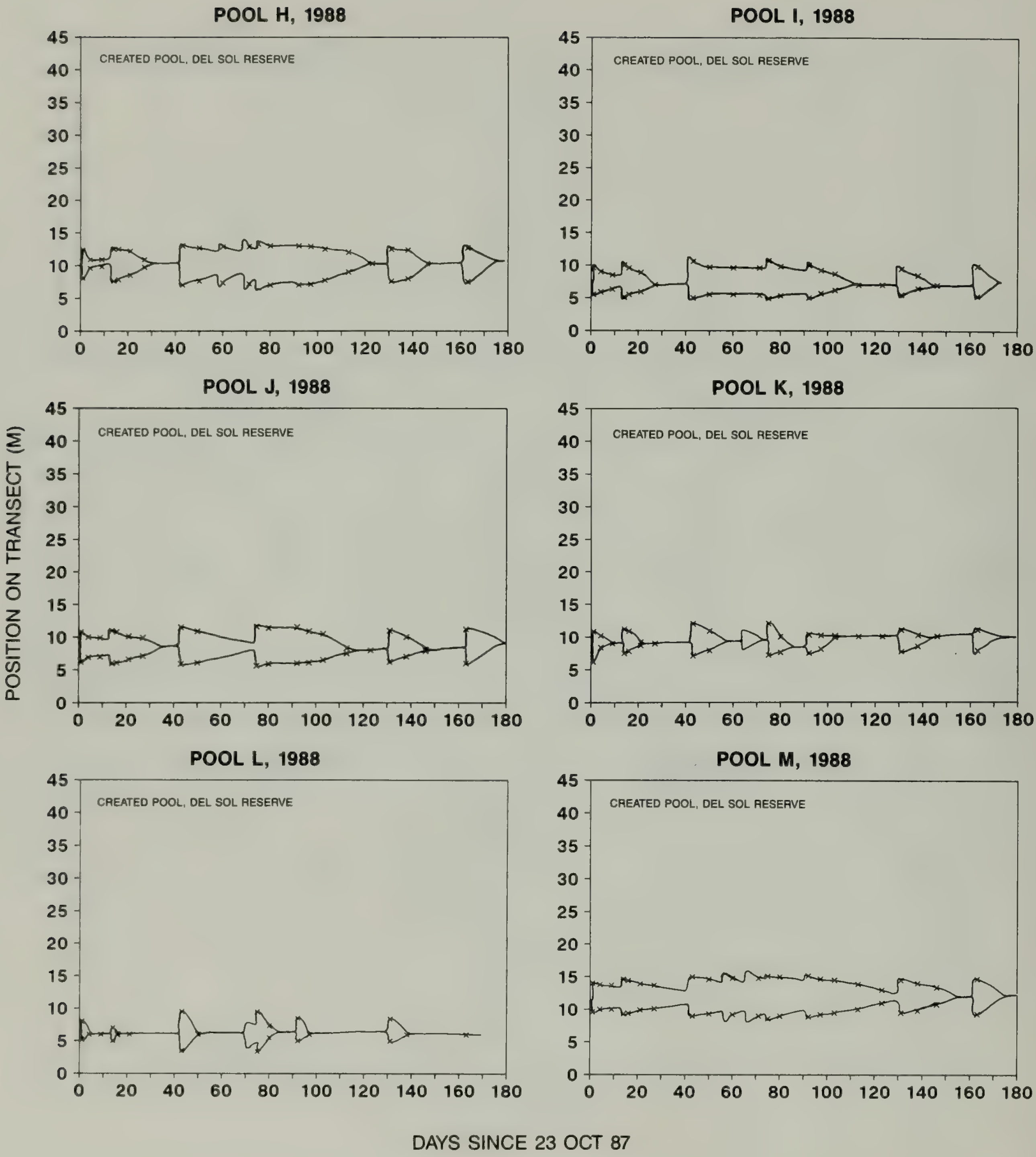

Fig. 37. HYDROLOGIC CONDITIONS IN 1988 OF VERNAL POOLS AT DEL SOL RESERVE AND ELLWOOD MESA. The area within each polygon indicates the extent and duration of flooding within each pool. Locations of pools are shown in Figure 14.

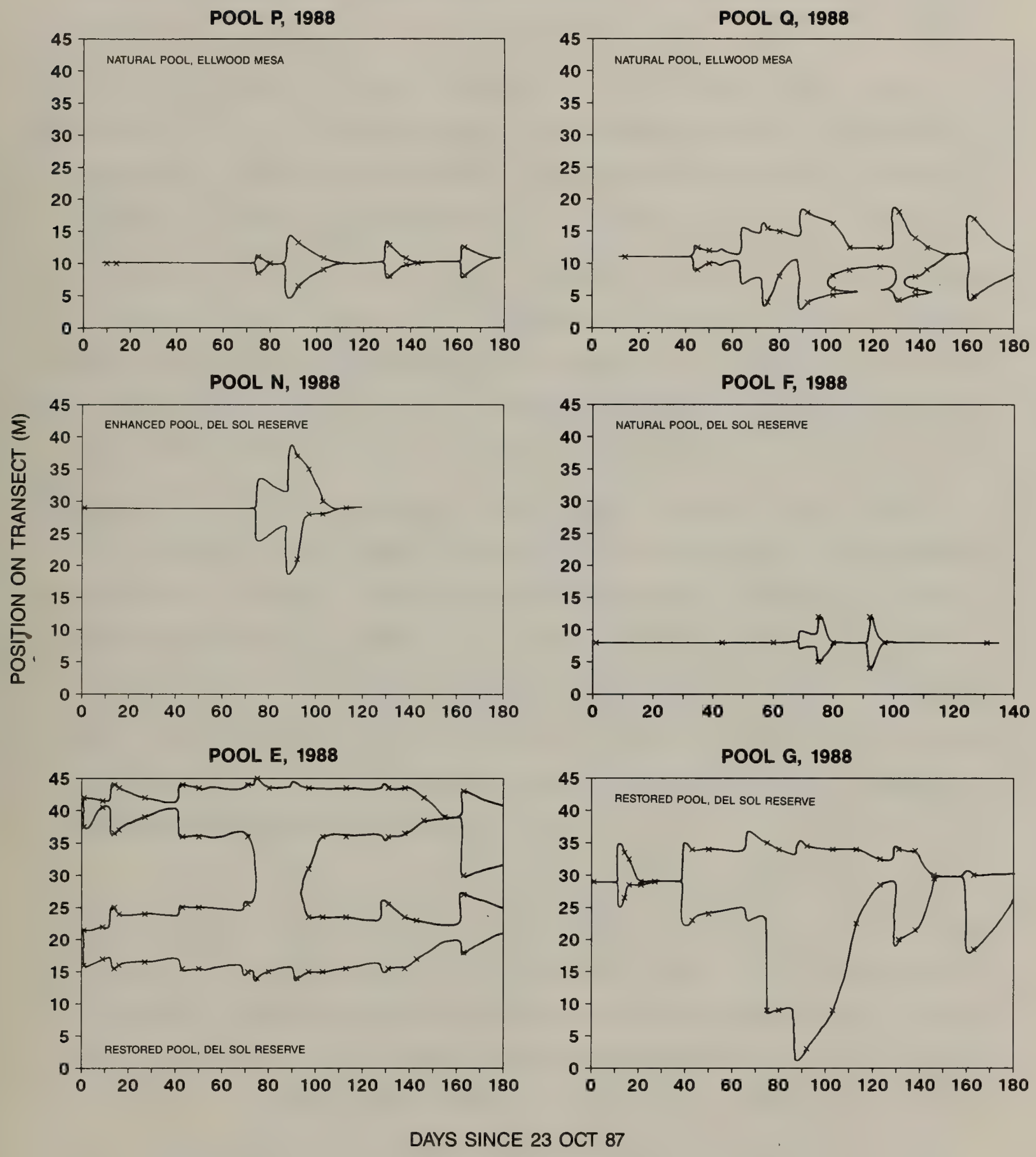

Fig. 37. Continued. Note: Horizontal axis is different for Pool F.

recharge significantly the extent of flooding in the remaining pools (Fig. 36).

Input from surface flow is a function of watershed area. Pools such as E, G, and N, which are in larger basins (Fig. 14), collected more water and are larger wetlands (Fig. 35). Although the average diameter of the basins is ca. 10 m, average diameter of maximum flooding during our study was ca. 7 m. Output from surface flow is minimal because the pools are within basins. None of the pools drain from the surface since the dams at Pools E and G were constructed. However, if many of the natural vernal pools in the Santa Barbara region originally occurred at seeps or in drainage troughs, surface flow may have been important historically before drainages were fragmented by roads.

Hydrologic input and output from subsurface flow and soil moisture storage are a function of soil hydraulic conductivity. This conductivity is inversely related to the clay content of soil, as well as other surface and subsurface features. A high clay content indicates low hydraulic conductivity and thus low subsurface flow and high moisture storage capacity. Pools H and M, for example, had a 40% clay content at 0.5 m depth (Table 1, samples 1 and 2, respectively). After these two created vernal pools were excavated, the clay layer occurred at the surface, a probable reason for the longer durations of flooding in these pools than in many of the Del Sol pools (Figs. 36 and 37). In Pools K and L, however, the duration of flooding was less than in the other four created pools, especially in the punctuated flooding of the 1987-88 season (Fig. 37), although the watershed area was equal or greater. A probable reason for the shorter durations of flooding in Pools K and L was that the clay layer occurred far enough below the surface to allow water infiltration instead of pooling.

In the restored pools, the greater basin area is reflected in the extent of flooding (Fig. 36, 37). Because the transect crossed two sub-basins, two areas of flooding are evident. They were joined to form one pool following sufficient rainfall. Duration of flooding for a portion of Pool E exceeded flooding of all other monitored pools.

In a comparison between created pools and natural pools, the created pools filled more quickly after rainfall and occasionally (e.g., 1988) also desiccated more rapidly than the larger natural pools. The soil of the natural pools seems to have a higher water holding capacity than created pools. This is perhaps a result of greater organic matter content (they support more biomass) and mud cracks that extend several decimeters in depth. The natural pools monitored may absorb more water before ponding occurs, but may also retain water for longer periods.

Soil Analysis. Data from the soil samples (Table 1) contributes to an understanding of the distribution of wetlands at Del Sol Reserve. All of the upland samples (nos. 5, 8 and 9, locations in Fig. 6) had a clay content of 12% or less at 0.5 m depth, whereas the wetland samples had a clay content of 23% or greater. Samples 1 and 2, originally located at upland habitat before the created pools were excavated, are an extreme exception to this trend, having a clay content of 40% or greater at 0.5 m depth. Apparently, the presence of a clay layer is not a certain indicator of an existing wetland habitat, (especially without the appropriate topographic features), but a clay layer may indicate an area that would be suitable for creating a wetland habitat. Had the created pools been located in an area with soil like sample 5, for instance, they may not have demonstrated appropriate hydrologic conditions because of the sandy soil there.

Plant Cover in All Pools. Table 4 shows all species encountered on the transects during the two years all pools were monitored. Pool N (the enhanced vernal pool) and Pool H (a created pool) also were monitored in 1986 to provide data about pre-project conditions. The botanic composition of each pool provides a general indicator of pool quality. Low quality vernal pools, as Pool F (an unenhanced natural pool) might be considered, support a high cover of naturalized weeds, whereas higher quality pools contain larger proportions of native species (Fig. 38) that are characteristic of vernal pool ecosystems.

Changes in the cover of species in the enhanced pool, Pool N, continue to be undesirable or ambiguous even after construction of the

dams. Undesirable changes include a decline in native species and an increase in naturalized species. For example, Eleocharis palustris, Phalaris lemmonii, and Plagiobothrys undulatus (Fig. 39), which are native species characteristic of vernal pools, decreased in cover over consecutive years, whereas Lolium multiflorum and Hordeum geniculatum, which are two naturalized species, increased in cover each year. Ambiguous changes include an increase in species cover one year followed by a decrease the following year. Hordeum brachyantherum, a native vernal pool species, exhibited this pattern.

Long-term changes in the enhanced pool are uncertain as determined from the data in Table 4. The pool was dominated by Lolium multiforum (92.7% cover) in 1988, an undesirable condition contrary to the goals of enhancement, but the rainfall this year and in 1987 was low. A year with exceptionally high rainfall might cause enough flooding to eliminate Lolium and other naturalized species. A year such as this would allow the full benefit of the constructed dams to occur. Reduced rainfall and extended lengths of time between storms result in a reduction in flooding that favors naturalized weedy species rather than native hydrophytes. Thus, our results probably do not reflect the ineffectiveness of the enhancement project (i.e., the constructed dam), but rather they simply reflect the result of suboptimum rainfall.

Cover of all species in the restored Pool G generally was higher the second year following excavation than in the first year. Total cover doubled (43.8% to 89.9%) during this period. This is not surprising given the amount of open substrate remaining available for colonization the second year. Pool G in 1988 experienced a significant increase in Lolium and declines in native species such as Eryngium vaseyi (Fig. 40), Eleocharis acicularis (Fig. 41), and Hordeum brachyantherum. This trend might be reversed after one or two years with optimum rainfall. Contrary to the results for Pool G, cover for many species declined in Pool E, particularly for the naturalized species Lolium multiflorum. Total cover declined from 59% to 37.4%. Cover for many native species, however, remained about the same (e.g., Erygium vaseyi, Eleocharis acicularis, Hemizonia australis).

TABLE 4. PLANT COVER IN VERNAL POOLS AT DEL SOL RESERVE AND ELLWOOD MESA.
Data are mean percent cover per plot per year for species encountered on the transects. Pools P and Q are at Ellwood Mesa; all others are at Del Sol Reserve, locations shown in Figure 14. e = enhanced; i = inoculated; n = natural; r = restored; u = uninoculated.

	Pool F (n)		Pool N (e)			Pool E (r)		Pool G (r)	
Species	12 May 87 N=7	13 Apr 88 N=7	29 Apr 86 N=13	12 May 87 N=8	12 May 88 N=13	14 May 87 N=16	30 Mar 88 N=18	15 May 87 N=18	13 Apr 88 N=19
Ambrosia psilostachya		0.1							
Anagallis arvensis	0.8	1.6				0.3	0.3	0.3	0.1
Avena barbata	3.9	2.7			1.2	4.8	4.2	0.3	2.1
Boisduvalia glabella									
Bromus diandrus			0.1			6.6	0.4	0.3	4.8
B. mollis						0.5	2.0		
Convolvulus arvensis									
Cotula coronopifolia			0.1						
Distichlis spicata									
Elatine brachysperma							0.1	0.1	
Eleocharis acicularis	57.1	37.1	1.5	27.5		0.1	0.1	3.5	1.6
E. palustris			54.7	40.1	0.5	0.1	0.5		
Erodium botrys	0.1	29.7				5.9	11.3		
Eryngium vaseyi	2.1	1.1		0.1		0.1	0.1	0.8	0.2
Foeniculum vulgare									0.1
Gastridium ventricosum									
Hemizonia australis		0.1				0.1	0.2		
Hordeum brachyantherum			22.5	33.1	14.7	0.1		16.3	3.0
H. geniculatum	34.3	6.6	4.6	5.0	10.2	5.1			0.1
Hypochoeris glabra	0.1								
Juncus bufonius		0.7				0.1	0.3		
Lactuca serriola		0.2		0.1	0.7				
Lolium multiflorum	80.0	44.3	17.7	60.0	92.7	32.5	15.0	21.7	76.3
Lythrum hyssopifolia						0.1	0.2		0.1
Medicago polymorpha							0.3		0.8
Orthocarpus densiflorus									
Phalaris lemmonii			0.8	0.6					
Pilularia americana			0.1						
Plagiobothrys undulatus		0.1	0.4	0.3					
Plantago lanceolata							0.1	0.1	0.1
Poa annua									
Polygonum aviculare							0.1	0.1	0.1
Polypogon monspeliensis									
Psilocarphus brevissimus									
Raphanus sativa								0.1	
Rumex crispus		0.2	5.4	0.8	0.2		0.1	0.1	
Sonchus oleraceus		0.8	0.1			0.1	0.1		0.1
Spergula arvensis						0.1	0.2		
Spergularia bocconii									
Vicia benghalensis		0.1			0.8	2.2	0.1		
V. sativa					0.4	0.1	0.6	0.1	
Vulpia bromoides	24.3	0.1	0.1		0.1	0.1	1.1		0.4
Total Cover	202.7	125.5	108.1	167.6	121.5	59.0	37.4	43.8	89.9

TABLE 4. (continued)

	Pool H (i)			Pool L (i)		Pool M (i)		Pool I (u)	
Species	9 Jul 86 N=12	8 May 87 N=6	26 Mar 88 N=11	7 May 87 N=6	25 Mar 88 N=12	22 Apr 87 N=4	26 Mar 88 N=11	5 May 87 N=6	26 Mar 88 N=10
Ambrosia psilostachya									0.1
Anagallis arvensis		0.3	2.7	1.4	1.5	0.5	1.3	4.5	2.6
Avena barbata	15.8	0.8	0.3	2.9	4.4		2.6	6.8	2.5
Boisduvalia glabella									
Bromus diandrus		0.2		1.3				0.2	
B. mollis									
Convolvulus arvensis		6.7		15.0	3.0	2.8	3.5		0.2
Cotula coronopifolia		0.1	0.3	0.6	0.5	0.3	0.7		
Distichlis spicata	21.7	16.0	5.9		0.1			2.1	2.4
Elatine brachysperma			0.1				0.5		
Eleocharis acicularis		0.3	1.2				2.1		
E. palustris							0.1		
Erodium botrys	41.7	12.7	12.9	9.2	15.5		17.3	5.8	10.0
Eryngium vaseyi									
Foeniculum vulgare									
Gastridium ventricosum	0.8								
Hemizonia australis	1.7	0.1		0.4	0.1		0.1		0.2
Hordeum brachyantherum									
H. geniculatum	5.8	0.3							
Hypochoeris glabra				0.1	0.4			0.2	0.1
Juncus bufonius		0.4	0.1	0.4	0.5	0.6	0.3	0.3	2.3
Lactuca serriola									
Lolium multiflorum	66.7	16.0	3.0	2.3	2.2	0.1	2.0	1.6	3.7
Lythrum hyssopifolia		0.2	0.7		0.3	0.1	0.8		
Medicago polymorpha									
Orthocarpus densiflorus					0.1				
Phalaris lemmonii									
Pilularia americana									
Plagiobothrys undulatus		2.0	1.3	0.3	0.4	0.6	1.0		
Plantago lanceolata			0.4	0.9	2.8	0.1	0.4		
Poa annua		0.1		0.7	0.3		0.1		
Polygonum aviculare									
Polypogon monspeliensis									
Psilocarphus brevissimus		7.8	17.5	21.0	11.9	6.5	8.5		0.1
Raphanus sativa								5.8	
Rumex crispus		0.1							
Sonchus oleraceus									
Spergula arvensis			0.1		0.6		0.6	0.2	0.5
Spergularia bocconii					0.1				
Vicia benghalensis		0.8	2.4		1.4			0.1	
V. sativa	1.7	0.9	0.6	0.3	1.3			2.6	
Vulpia bromoides	25.0	1.3	7.1	3.1	19.7	0.1	4.5		4.9
Total Cover	180.9	67.1	56.6	59.9	67.1	11.7	46.4	30.2	29.6

TABLE 4. (continued)

	Pool J (u)		Pool K (u)		Pool P (n)		Pool Q (n)	
Species	5 May 87 N=5	25 Mar 88 N=11	12 May 87 N=5	25 Mar 88 N=10	22 May 87 N=9	16 May 88 N=16	20 May 87 N=11	11 May 88 N=19
Ambrosia psilostachya	2.0	0.5	8.2	2.5				
Anagallis arvensis	0.4	0.6	5.2	3.1			0.1	0.1
Avena barbata	5.2	3.2	0.1	0.7				
Boisduvalia glabella							0.1	
Bromus diandrus	0.1							
B. mollis						0.1	0.5	0.4
Convolvulus arvensis	8.2	1.0		0.1				
Cotula coronopifolia					4.7	2.6	0.7	5.8
Distichlis spicata		0.1						
Elatine brachysperma								
Eleocharis acicularis					56.1	45.1	41.9	31.6
E. palustris				0.1	0.8	2.3	3.6	4.8
Erodium botrys	18.2	15.3	22.0	7.3	0.1	0.1	0.1	
Eryngium vaseyi					23.3	29.1	24.7	13.4
Foeniculum vulgare								
Gastridium ventricosum								
Hemizonia australis					0.3	0.3	0.5	0.6
Hordeum brachyantherum					0.3	2.6		
H. geniculatum					33.7	45.1	34.4	38.3
Hypochoeris glabra	0.1	0.1		0.1	0.1	0.2		0.5
Juncus bufonius	0.2	1.1	0.3	0.9				
Lactuca serriola			0.1					
Lolium multiflorum	3.0	4.2	4.6	6.8	16.9	40.4	3.1	2.5
Lythrum hyssopifolia					1.1	0.3	0.5	0.9
Medicago polymorpha								
Orthocarpus densiflorus								
Phalaris lemmonii					0.1	0.1		
Pilularia americana								
Plagiobothrys undulatus		0.1			2.9	1.2	3.4	2.6
Plantago lanceolata		0.1			0.3	0.7	5.5	8.1
Poa annua					0.2		0.2	0.2
Polygonum aviculare					0.2		3.9	0.2
Polypogon monspeliensis					4.1	8.1	2.0	8.8
Psilocarphus brevissimus		0.1		0.1	0.3	0.1	19.1	4.5
Raphanus sativa								
Rumex crispus		0.1	4.0	0.5	0.1	0.1	1.0	0.2
Sonchus oleraceus							0.1	
Spergula arvensis	0.1	0.1	0.2	0.3				
Spergularia bocconii								0.1
Vicia benghalensis			8.0	0.1		0.1		
V. sativa	0.1		0.1		0.1			0.1
Vulpia bromoides	4.2	2.3	0.8	5.2	0.3	0.8	5.6	3.9
Total Cover	41.8	28.9	53.6	27.8	146.0	179.4	151.0	127.6

As in the restored pools, plant cover in the inoculated created pools (Pools H, L, and M) provided mixed results but generally was higher the second year following excavation than in the first year. Unlike restored Pool G, however, this increase in cover included most of the native vernal pool species. Psilocarphus brevissimus (Fig. 42), a species endemic to vernal pools, had a relatively high cover (6.5-21%) in Pools H, L and M, where it was introduced as part of the seed bank acquired from Pools P and Q. The reduced total cover from 1987 to 1988 in created Pool H was due largely to the decrease in cover of the naturalized species Lolium multiflorum.

Apparently, hydrologic or other environmental conditions in the inoculated created pools were more favorable for native species than conditions present in the enhanced or restored pools. Invasive naturalized species such as Lolium were not much of a problem in the created pools. For example, Lolium was common (66.7% cover) at the site of Pool H before the pool was excavated in 1986, but this species has diminished.

Unlike the inoculated created pools, the uninoculated created pools had a consistent decline in total cover from 1987 to 1988 (Table 4). This was due largely to the general diminished cover of naturalized upland species such as Erodium botrys, Avena barbata, and Convolvulus arvensis. However, there was an increase in aquatic species (e.g., Juncus bufonius) and in 1988 several vernal pool species (e.g., Psilocarphus brevissimus, Hemizonia australis) appeared even though seed bank material had not been added. Thus, the decline in total cover for these pools is not a measurement of pool quality or success of the project. Instead, total cover includes both a decline in cover for naturalized species and an the increase in cover or establishment of native vernal pool species.

The natural vernal pools from Ellwood Mesa (Pools P and Q) had the greatest cover of native vernal pool species among all monitored pools (Table 4). Pool cover and composition reflects quality conditions even

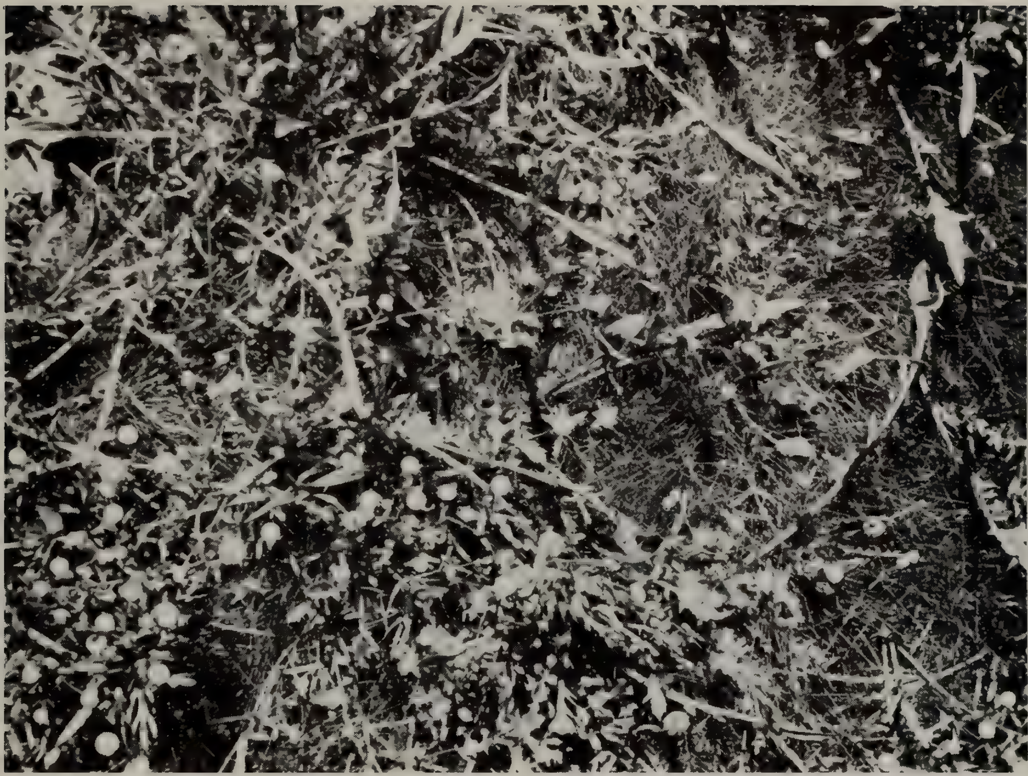

Fig. 38. PLANT SPECIES STUDIED IN THE POST-PROJECT MONITORING PROGRAM. A diverse assemblage of plants occurred in the monitored vernal pools, especially in the natural pools of Ellwood Mesa (shown here) and the inoculated created pools of Del Sol Reserve. Native hydrophytes in this photograph include *Eleocharis acicularis, Eryngium vaseyi,* and *Plagiobothrys undulatus.*

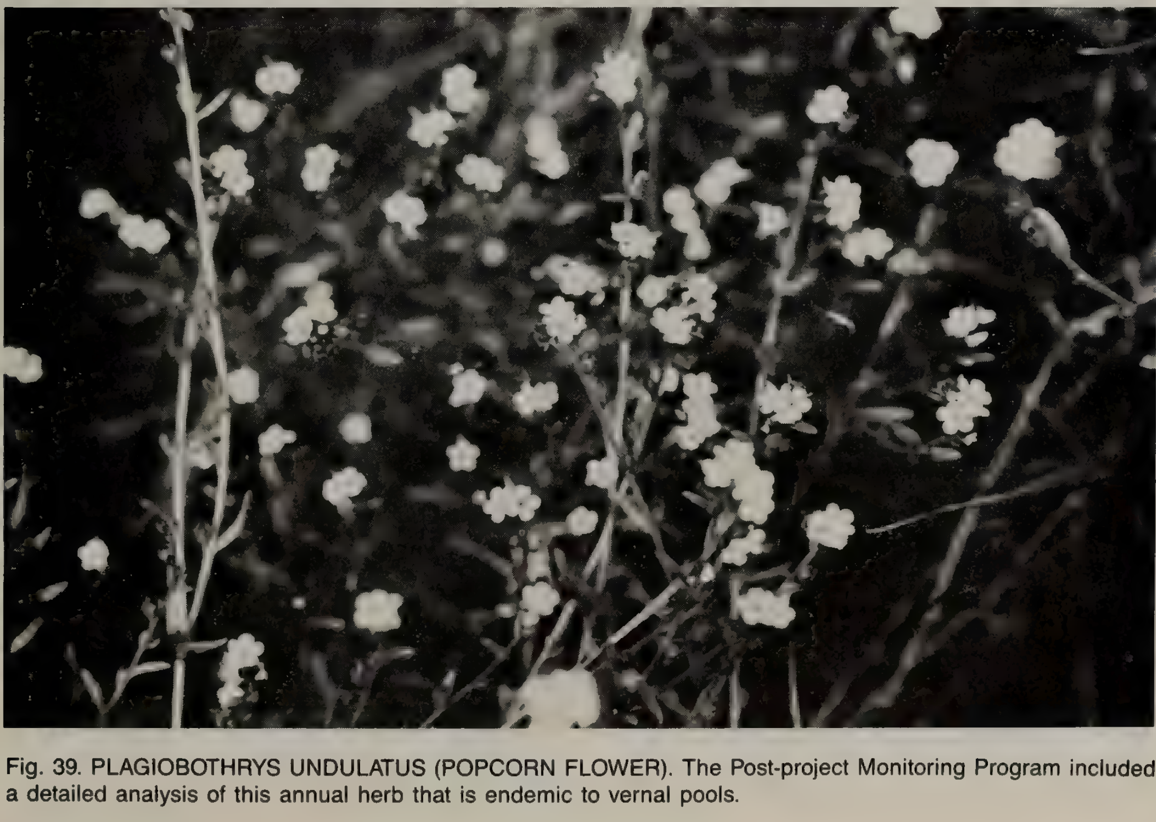

Fig. 39. PLAGIOBOTHRYS UNDULATUS (POPCORN FLOWER). The Post-project Monitoring Program included a detailed analysis of this annual herb that is endemic to vernal pools.

Fig. 40. ERYNGIUM VASEYI (COYOTE-THISTLE). This perennial herb is endemic to vernal pools and reaches its southernmost point of distribution in the Santa Barbara area. Its response to habitat manipulation was studied in detail during the Post-project Monitoring Program.

Fig. 41. ELEOCHARIS ACICULARIS (NEEDLE SPIKE-RUSH). This perennial rhizomatous herb occurs in many types of wetland throughout North America, but in the Santa Barbara area it is restricted to vernal pools. It was included as part of a detailed vegetational analysis in the Post-project Monitoring Program.

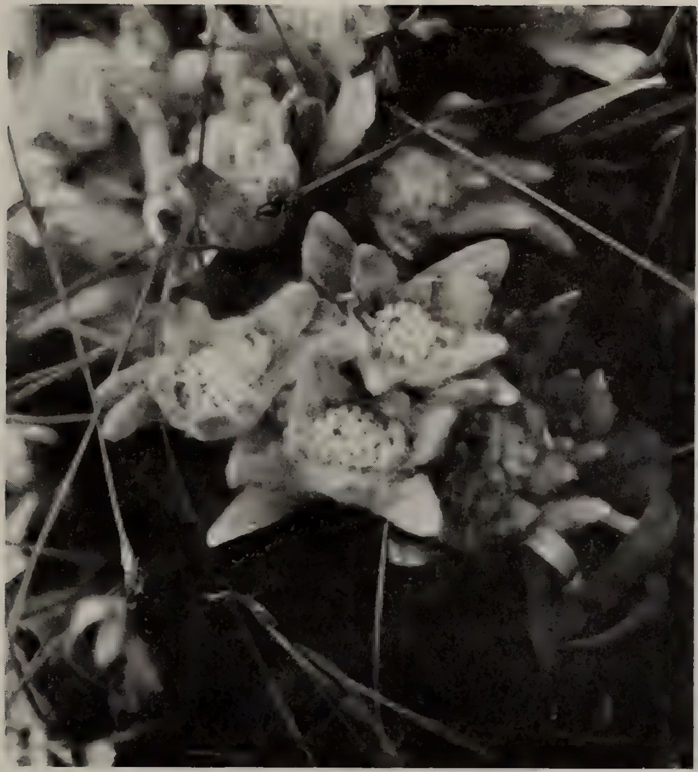

Fig. 42. PSILOCARPHUS BREVISSIMUS (WOOLLY HEADS). This annual herb is endemic to vernal pools. Its response to habitat manipulation was analyzed in detail in the Post-project Monitoring Program.

Fig. 43. LYTHRUM HYSSOPIFOLIA (LOOSESTRIFE). This perennial hydrophytic herb occurs throughout North America. Its response to habitat manipulation was studied in detail during the Post-project Monitoring Program.

during periods of suboptimum rainfall. High estimates of cover also were recorded for natural Pool F and enhanced Pool N at Del Sol Reserve, but the cover included greater values for naturalized species reflecting the drier and more disturbed habitats.

Species Abundance in Created and Natural Pools. A comparison of ten species abundances (Fig. 44) provides an alternative analysis in which data from each type of pool (created or natural) are combined. The Index of Abundance, a type of importance value, was calculated from plant cover and density monitored the first spring (in 1987) after the pools were created.

Nine possible histograms represent each species according to the three class of flooding for the three treatments of pools. The three classes of flooding are: areas flooded for one or more days, areas within 1 m of flooding, and areas further than 1 m from flooding. The three treatments are: natural pools (Pools P and Q), pools inoculated with a seed bank obtained from the natural pools (H, L and M), and uninoculated pools (I, J,and K). Histograms that do not appear on the graphs in Figure 44 have an abundance rating of zero.

The higher abundance of the naturalized aquatic plant <u>Cotula coronopifolia</u> and the native vernal pool plants <u>Eleocharis acicularis</u>, <u>Lythrum hyssopifolia</u> (Fig. 43), and <u>Eryngium vaseyi</u> in the inoculated pools than in the uninoculated pools suggests that the introduction of a seed bank was an effective method to establish these four plants in the created pools. As the populations and individual sizes of these species grow, the created pools eventually might support abundances comparable with the natural pools at Ellwood Mesa.

The apparent absence of <u>Psilocarphus brevissimus</u> and <u>Plagiobothrys undulatus</u> from the uninoculated pools and the higher abundances of these two plants in the inoculated pools suggests that the introduced seed bank also was an effective method to establish these native plants in the created pools. Furthermore, the higher abundances of these species in the inoculated created pools compared with the natural pools

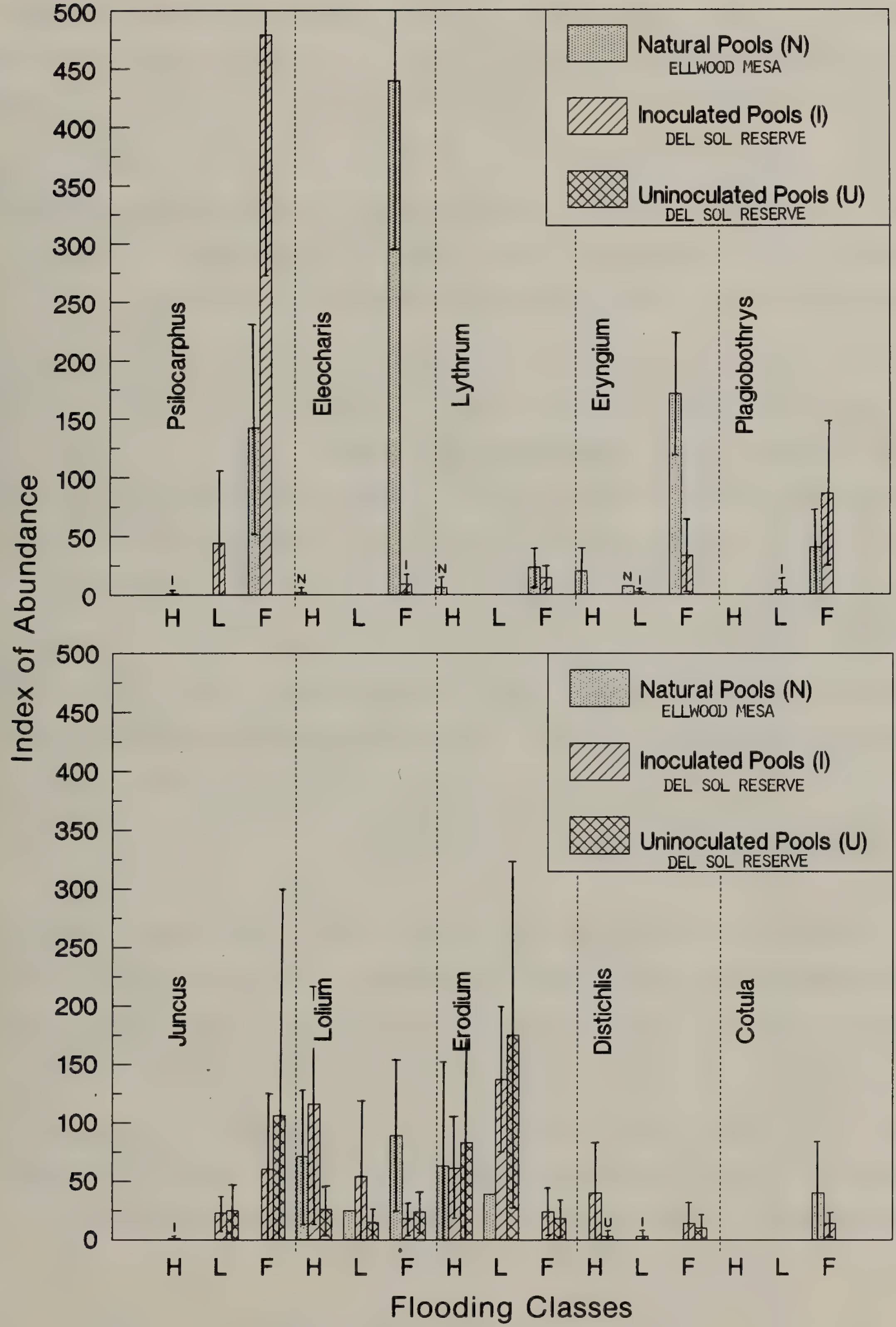

Fig. 44. PLANT ABUNDANCES FOR CREATED AND NATURAL POOLS, 1987. Relative abundances for 10 species are shown for three flooding classes: areas flooded for one or more days (F), areas within 1 m of flooding (L), and areas further than 1 m from flooding (H). Error bars are two standard errors of the mean.

indicates that the created pools, for the first year of their existence, were superior habitat for these two plants. The open substrate of the created pools probably allowed many seeds of these two annual plants to germinate and grow without competition from other plants. The denser cover of perennial plants in natural vernal pools undoubtedly would prevent the high abundances of Psilocarphus and Plagiobothrys that were observed in the inoculated created pools. Eventually, as perennial species mature, the annual species may decrease in abundance.

The higher abundance of Juncus bufonius and Distichlis spicata in the created pools also may be a result of the open substrate available in the created pools. Juncus bufonius seems to be an opportunistic species that colonizes vernal pools. This species may not have been part of the introduced seed bank because its abundance was the same or greater in the uninoculated pools as compared to the inoculated pools. Distichlis spicata also seems opportunistic, and also probably was not part of the introduced seed bank. It is common in the surrounding grassland habitat and may have colonized from undisturbed upland adjacent to the created pools. Lolium multiflorum and Erodium botrys, two naturalized weedy plants, do not appear to have consistent distributions among the pools, but in the created basins they seem to occur more abundantly outside flooded areas.

Floras of the Created and Natural Pools: The floras from the three treatments of pools (Table 5) indicate that the natural pools had 14 native species. Ten of those 14 occurred in the inoculated created pools (eight of the ten were native species characteristic of vernal pools), and five of those 14 occurred in the uninoculated created pools (four of the five were native vernal pool species). As with the monitoring of plant abundances discussed above, the floras of the pools were surveyed only during 1987, the first year following creation of the pools.

The higher similarity of native flora between the natural pools and the inoculated pools rather than between the natural pools and the uninoculated created pools probably was a result of the introduced seed

TABLE 5. FLORAS OF NATURAL AND CREATED VERNAL POOLS, 1987.
Data are combined from two natural pools at Ellwood Mesa, three inoculated created pools at Del Sol Reserve, and three uninoculated created pools at Del Sol Reserve. Native species are indicated by an asterisk. † = vernal pool species.

Species	Natural Vernal Pools	Inoculated Created Pools	Uninoculated Created Pools
Ambrosia psilostachya var. californica*		x	x
Anagallis arvensis		x	x
Avena barbata	x	x	x
Boisduvalia glabella*†	x		
Bromus diandrus		x	x
B. hordeaceus	x	x	
Calandrinia maritima*		x	x
Callitriche marginata*†	x	x	
Convolvulus arvensis		x	x
Cotula coronopifolia	x	x	
Crassula aquatica*†	x	x	
Cynodon dactylon	x		
Cyperus eragrostis*	x		
Distichlis spicata var. spicata*		x	x
Elatine brachysperma*†		x	x
Eleocharis acicularis*†	x	x	x
E. palustris*	x		
Eremocarpus setigerus*	x	x	x
Erodium botrys	x	x	x
E. cicutarium	x	x	x
Eryngium vaseyi*†	x	x	x
Geranium dissectum	x		
Hemizonia australis*†	x	x	
H. fasciculata*	x		
Hordeum brachyantherum*†	x		
H. geniculatum		x	
H. murinum		x	
Hypochoeris glabra	x		
Juncus bufonius*		x	x
Lactuca serriola		x	
Lolium multiflorum	x	x	x
Lythrum hyssopifolia*	x	x	x
Medicago polymorpha	x		
Phalaris lemmonii*†	x		
Plagiobothrys undulatus*†	x	x	
Plantago lanceolata	x	x	x
Poa annua	x	x	
Polygonum aviculare	x		
Polypogon interruptus	x		
P. monspeliensis	x	x	
Psilocarphus brevissimus*†	x	x	
Rumex crispus	x		
Sonchus asper		x	
S. oleraceus		x	
Spergula arvensis	x	x	x
Spergularia bocconnii	x	x	x
S. villosa	x		
Vicia benghalensis	x	x	x
V. sativa	x		
Vulpia bromoides		x	x

bank obtained from the natural pools. Although Eleocharis, Erynigum, and Lythrum had a sampled abundance of zero in the uninoculated pools (Fig. 44), the presence of these three species in the uninoculated pools (Table 5) suggests that wind, birds, or other animals (e.g., ecologists) could have dispersed the seeds of these three plants from the inoculated pools (H, L, and M) to the uninoculated pools (I, J, and K) (Zedler 1987).

Faunas of the Created and Natural Pools. The invertebrate fauna (Table 6) of the enhanced pool (Pool N), an inoculated created pool (Pool M), an uninoculated created pool (Pool J), and a natural pool (Pool Q) was sampled once in each pool at various times in 1987 and 1988. Although this sampling was inadequate to produce an exhaustive list, we did find various aquatic insects, crustaceans, and a spider. However, we found no rotifers, a diverse phylum known to occur in San Diego vernal pools (Balko and Ebert 1984).

Faunal communities in vernal pools and similar aquatic habitats change composition rapidly and can vary significantly among pools (Balko and Ebert 1984, Dubbs 1987). A precise comparison among the pools, therefore, is impossible because most of them were sampled months apart. Nevertheless, the data in Table 6 do provide a one-time sampling of each pool. Of particular interest is the hundredfold greater number of ostracods in Pool M (which received vernal pool inoculum) and Q (source of inoculum) than in Pool J (uninoculated). This difference may indicate that inoculating the created pools introduced invertebrate animals as well as plants. Crustaceans have nesting stages in the sediments when pools are dry and, in particular, may be affected by the relocation of sediment as well as plant material. As in studied San Diego vernal pools (Dubbs 1987), crustaceans were the most abundant organisms in the samples.

The inoculated pools visually appeared to have clear water (reduced turbidity) associated with the native aquatic plants and animals in 1987 and 1988, whereas the uninoculated pools appeared cloudy with suspended particulate material occurring even in the second season

TABLE 6. INVERTEBRATE FAUNA OF VERNAL POOLS AT DEL SOL RESERVE AND ELLWOOD MESA. Locations of pools are shown in Figure 14. Dates are when sampling occurred. n = natural pool at Ellwood Mesa; i = created pool inoculated with seed bank material, u = uninoculated created pool, and e = enhanced pool at Del Sol Reserve.

ARTHROPODA	Pool N (e) 11 Mar 88	Pool M (i) Nov 87	Pool J (u) Nov 87	Pool Q (n) 10 Feb 88
Insecta[1]				
Collembola - Springtails				
Sminthuridae	1			
Ephemeroptera - Mayflies				
Baetidae				
Callibaetis sp.		1		
Diptera				
Culicidae - Mosquitoes				
Aedes sp.	23		1	
Chironomidae - Midges				
Tanytarsini (Tribe)			1	
Dolichopodidae			1	
Hemiptera				
Corixidae - Waterboatmen				
Graptocorixa sp.		10		
Notonectidae - Backswimmers				
Buenoa scimitra				1
Aphididae (terrestrial)	11			
Odonata - Dragonflies (& Damselflies)				
Libellulidae				
sp. 1			3	
sp. 2			4	
CRUSTACEA				
Isopoda - Sowbugs				
Armadillidium vulgare[2]	1			
Ostracoda - Seed Shrimp				
Cypridae		500	2	240
Copepoda -Copepods				
Cyclopoida (*Cyclops* & *Eucyclops*)	60		8	160
Cladocera - Water fleas				
Chydoridae (sp. 1)				1
Moinidae				
Moina sp.				600
Daphnidae				
Ceriodaphnia sp.		8		
ARACHNIDA				
Araneidae (sp. 1)[3]	1			

[1] = Most of these insects colonize from terrestrial adults, so unlike the crustaceans they are not as dependent on resting stages in the sediments.

[2] = May forage partly underwater.

[3] = Often forages onto water surface near vegetation.

of flooding. Thus, the newly established ecosystem in the inoculated pools may have had effects on water quality as well as species richness and density.

Mosquito Abatement Policies

The result of negotiations between the IVRPD and the Goleta Valley Mosquito Abatement District (GVMAD) was a "Cooperative Agreement between IVRPD and GVMAD" (10 Aug 1987), with an addendum that describes the abatement activities. The document states that both agencies "...wish to enter into a Cooperative Agreement to protect the public's health from injurious and disease transmitting mosquitoes and to assure safe, effective, and environmentally acceptable use of mosquito prevention and control technology on this sensitive area..." The Agreement indicates that GVMAD will provide surveillance of breeding areas, maintain records, and use acceptable materials, and that IVRPD will give access to the Reserve, results of studies, and reimbursement for control costs. The Agreement also states that IVRPD will establish "...a management plan or policy for the control of exotic and noxious species..." GVMAD is particularly concerned about Scirpus californicus (California Bulrush) and Typha spp. (Cattails) because these plants can compound the mosquito problem in vernal wetlands. The Vector Surveillance and Control Branch of the California Department of Health Care Services will mediate any differences arising between parties in the implementation of the Agreement.

Although GB 1356 may continue to be used as insecticide, GVMAD also proposes to use Vectobac-G, which is a biological mosquito larvicide composed of a granular formulation containing Bacillus thuringiensis (Stannard 1986). The larvicide contains spores and deltaendotoxins that have insecticidal activity primarily limited to mosquitoes and black flies (Stannard 1986). It is more expensive ($11.40 per acre) than GB 1356 ($7.74 per acre), but may provide a better approach to killing mosquitoes in sensitive habitats.

Public Information

<u>Brochure and Booklet</u>. Increasing public awareness of the values of vernal pool habitats, Del Sol Reserve, and the Enhancement Plan was an important goal of the project and was one of the tasks specified in the Enhancement Plan. In addition to interpretive signs that were placed at various sites on the Reserve, we assisted the public awareness goal and fulfilled the contract task by developing an interpretative brochure, "Del Sol Open Space and Vernal Pool Reserve" (Appendix IV) and a booklet, "Vernal Pools of the Del Sol Reserve" (Appendix V).

The brochure is available free of cost at Del Sol Reserve, the Isla Vista Recreation and Park District (IVRPD) office, and the UCSB Herbarium. Included in the brochure are a map of the Reserve, a brief explanation of vernal pools and the Enhancement plan, and drawings of some species found at the Reserve. The 16-page booklet is available for a small charge at IVRPD. Compared with the brochure, the booklet includes a more detailed explanation of vernal pools, the significance of the Reserve and the Enhancement Plan, and more illustrations of vernal pool organisms. These two documents were produced to assist with the development of public support and appreciation for this unique resource in an urban setting.

SIMILAR PROJECTS AND SITES

The "Del Sol Vernal Pools Enhancement Plan" is one of at least 16 projects or activities that have been implemented or planned in California for enhancement, restoration, or creation of vernal pools. The additional projects occur in four regions: 1) northern California in Shasta County; 2) Central California largely in the Sacramento and San Joaquin valleys; 3) southern California in coastal Santa Barbara County; and 4) southern California in San Diego County. Information regarding these projects has come from publications, reports (particularly Zedler 1986), personal observations, and personal communications.

Northern California

Rancho Buena Vista, Shasta County. This sole northern California project is located 10 miles southeast of Redding in northern Sacramento Valley. Rancho Buena Vista is privately owned property that includes about 650 acres of valley grassland (Zedler 1986). Prior to 1982, a large vernal pool had been formed by an earthen dam that blocked drainage of a vernal swale (R. Holland, pers. comm., 1988). This altered wetland provided habitat for Orcuttia tenuis Hitchc. (Slender Orcutt Grass), a state endangered species and a federal candidate endangered species (Smith and Berg 1988).

Because this first pool was to be eliminated by a proposed development, a second wetland was created by removing topsoil from a swale to make the habitat deeper, and a dam was constructed to retain water (Zedler 1986). The result was a basin that covered about 3.5 acres and filled with winter rain to a depth of over 2 ft. The revegetation effort was specific to only O. tenuis, the seeds of which were gathered from the first basin and introduced into the second basin in 1982 (R. Holland, pers. comm., 1988). An evaluation of the site in 1985 revealed about one-third as many individuals of O. tenuis per unit area as existed in the original pool, and additional vernal pool species also occurred (Zedler and Black 1988). Holland (pers. comm., 1988)

reports that one problem with the second basin is that parts of it are too deep and retain water too long, permitting freshwater marsh vegetation to establish rather than vernal pool vegetation. This problem of excessive flooding in an excavated swale is similar to other projects discussed herein (e.g., Coal Oil Point Reserve).

Central California

Davis Interchange, Solano County. Eight pools containing 12 basins were created by CALTRANS in a highway island basin at the intersection of Highways 80 and 113 in summer 1986 (Zentner 1988; S. Chainey and C. Martz, pers. comm., 1988). The creation of vernal pools was an experiment in landscaping and had nothing to do with project mitigation or biological enhancements (S. Chainey, pers. comm., 1988). The spring wildflower display was proposed by Professor K. Dawson, Center for Design Research at UC Davis, as a low maintenance, native plant alternative to traditional, high-cost highway landscaping (S. Chainey, pers. comm., 1988).

A construction drawing, location of donor pools, and assistance with implementation of the project was provided by S. Chainey (pers. comm., 1988) a graduate student at UC Davis at the time, who also provided the following information. After identifying sites in the region that potentially supported vernal pools and that were under an imminent threat of destruction by development, he located property owned by Chevron, Inc. near Vacaville (14 miles from the creation site) that could be used for soil and seed bank material. At this donor site, the top soil was removed first, and then the subsoil to 18 inches, a practical depth for excavation. Fourteen dumpster loads of soil were moved to the project site. The subsoil was spread over the excavated basins, mixed with bentonite clay (formed of decomposed volcanic ash), pulverized, wetted, and compacted to 95%, about the soil density measured at the natural site. The top soil was applied dry and compacted. Additional seed and litter was obtained from pools at the Jepson Prairie Reserve. The result was 12 nearly identical basins (eight individuals, four of which had an additional basin constructed

adjacent to and apparently part of them resulting in 12 basins). The created basins are approximately 30 feet in diameter and 12 inches deep, and correspond to the average dimensions of the Vacaville pools.

Two years of post-construction monitoring have revealed (Zentner 1988) that, by the end of the summer 1987, average pool vegetative cover was 40% and plant species richness averaged nine species per pool, whereas in June 1988, total vegetative cover was 60-70% and total species richness averaged 12 species per pool. In both surveys, vernal pool species dominated the vegetative cover. Additional information on the first year monitoring program is contained in Owen (1987). Chainey (pers. comm., 1988) notes the created pools as medium to high in quality for species richness, rareness, and cover. Martz (pers. comm., 1988) however, suggests that the pool morphology may be too steep. He has observed extended ponding, but he has not observed species indicative of freshwater marsh habitats. As in the Del Sol example, the Davis project demonstrates that at least in the short-term analysis the created habitat supports native vernal pool species.

Myres Ranch, Merced County. Thousands of acres of "superlative vernal pool habitat" (R. Holland, pers. comm., 1988) occur in this region of San Joaquin Valley. Two borrow pits, each about two acres in area, were excavated in the 1950's to create a berm (Zedler 1986). No seed bank material was added to the excavated sites, but natural vernal pools occur nearby and apparently are the source of propogules that have colonized the sites (R. Holland, pers. comm., 1988). After 30 years of unassisted recovery, most species present in the natural pools occur in the excavated pools, but plants in the latter pools do not occur in distinctive moisture gradient zones, and the pools do not have a natural appearance (Zedler 1986).

Davis Aubudon Reserve, Yolo County. In the mid-1970's, two basins were created on a site formerly used for sewage treatment settling ponds (Zedler and Black 1988). The sites had saline clay soil and were dominated by weeds prior to excavation (R. Holland, pers. comm., 1988). One basin was flooded for only short periods and supported largely exotic

grasses, whereas the other pool was flooded too long and supported largely cattails and sedges (Zedler and Black 1988). Zedler and Black (1988) cite S. Chainey and E. Bauder who were unable to find vernal pool plants in the basins in 1985. As in several other examples, duration of flooding was apparently a key factor in the future of the project.

Folsom, Sacramento County. Three circular pools were created in June 1987 by River West Developments under the direction of the California Department of Fish and Game (Zentner 1988). This vernal pool project was implemented to mitigate possible impacts for a development that has not been constructed (J. Zentner, pers. comm., 1988). Soil and seed bank material were removed from natural pools to be destroyed and were placed in the new pools (L. Stromberg, pers. comm., 1988). Stromberg (pers. comm., 1988) produced a checklist for the created pools in April 1988 and found 23 plant species, of which 20 were vernal pool or wetland species. He noted, however, that the pools did not have the appearance of natural pools and probably did not function naturally.

Phoenix Park Ecological Reserve, Sacramento County. This reserve near Sacramento includes eight to ten acres of vernal pool habitat that were degraded by dirt bike activity (Zedler and Black 1988). Enhancement of the site was achieved by placement of a fence to eliminate these perturbations. Holland (pers. comm., 1988), who has observed the site for more than ten years, indicates that recovery has been remarkable and that the casual observer would not be able to locate the damaged areas. In this example, fencing without further manipulation was enough to promote recovery.

Fair Oaks, Sacramento County. In 1983, R. Holland (pers. comm., 1988) created a vernal pool on his property near Sacramento. He excavated a basin, lined it with plastic to simulate an imperious layer, and placed soil and seed bank material over the plastic to a depth of about 8 inches. The soil and plant material came from vernal pools that were being destroyed in the Roseville area. Holland found that the new pool flooded for no more than ten days at a time. The shallow soil over plastic seemed to prevent some plant growth, possibly

because of extreme desiccation. Eryngium vaseyi, for example, occurred only in the outer ring of vegetation where the soil does not cover the plastic. Holland added domestic water to compensate for the rapid rate of evaporation, but the chlorine in the water apparently killed many of the vernal pool invertebrates that were transferred with the soil. Weeds have become a problem in the pool, particularly Polygonum sp. and exotic grasses such as Glyceria sp. and Hordeum sp. (Holland, pers. comm., 1988).

University of California at Berkeley Botanical Garden, Alameda County. Two vernal pools were created at the University Botanic Garden in Berkeley. The first pool apparently was created in the 1950's for experimental work with Lasthenia spp. and Downingia spp. (R. Ornduff, pers. comm., 1988). A depression was dug, lined with cement,and covered with a thin layer of greenhouse soil. This pool was demolished eventually. The second pool was created ca. 1965 and measures about 12 x 8 ft. It also is lined with cement, but the cement has cracked and should be replaced (H. Forbes, pers. comm., 1988). Rainfall is supplemented by artificial irrigation with tap water (R. Ornduff, pers. comm., 1988). In the past, the soil was sterilized each year and the pool was replanted. This has not been done recently and the pool has been dominated by weeds, although Limnanthes sp. and Eryngium sp. persist (H. Forbes, pers. comm., 1988). Downingia seed, however, was gathered from "the wild" [i.e., Jepson Prairie] and reintroduced annually (Zedler 1986). This is the only example we have found where a vernal pool was created in a botanic garden setting and where concrete was used to produce an impervious layer.

Laguna Creek (Phase I), Sacramento County. Two pools were created in Sacramento by Zentner & Zentner in fall 1987 (Zentner 1988). This project was a pre-mitigation experiment to determine the feasibility of creating vernal pools in this area (J. Zentner, pers. comm., 1988). At the end of the first season of growth, plant cover in the pools was 75%, and 39 plant species were observed of which 25 were vernal pool or wetland species. Natural vernal pools adjacent to the project pools were used as a reference for monitoring the vegetation (J. Zentner,

pers. comm., 1988). The reference pools contained 10-18 species, 65% of which were vernal pool or wetland species (Zentner 1988). Zentner also cites a personal communication from J. Singleton in which invertebrate populations and species richness are stated to have been replicated successfully. Thus, with this project there again is short-term evidence that plants and animals can establish in created vernal pool habitat. The mitigation plan for the urban development project in the Laguna Creek Assessment District is based in part on these findings.

Laguna Creek (Phase II), Sacramento County. In the Laguna Creek Assessment District, the City of Sacramento proposed a modified stream corridor, flood protection structures, urban development projects, and parks along Laguna Creek (Zenter & Zentner, 1988). A mitigation program prepared by Zentner & Zentner (1988) proposed that the City compensate for the destruction of existing wetlands by creating 44.8 acres of vernal pools, 18.6 acres of freshwater marsh and ponds, and 12 acres of riparian woodland on city lands in and adjacent to the stream corridor. Two large vernal pools and a freshwater seasonal marsh were proposed for on-site preservation in addition to the created wetlands. Also required for this project are the creation of 63.3 acres of vernal pools, seasonal open water and marsh lands, and riparian woodland on lands owned by the Sacramento Regional County Sanitation District. The mitigation program proposed by Zentner & Zentner (1988) "...provides for the preservation of 3.3 acres of vernal pools and the restoration of 82.7 acres of vernal pools (an area restored : area lost ratio of 2.2:1)... The habitat values lost will be restored through the re-creation of similar and higher value habitats."

A vernal pool seed collection and storage program and a vernal pool soil salvage program also were proposed as part of the project. Preproject monitoring determined that a hardpan or cemented layer is present, and subsequently the artificial vernal pools were proposed for the area with a hardpan (Zentner & Zentner 1988). A five year monitoring program also is proposed "...to assess the success of all restoration efforts; elements of the program determined to be operating below specific performance standards shall be corrected by the

maintenance district (to be formed as a requirement of the project)". Other post-construction monitoring activities proposed include measurements or observations of water depth and flood frequency, plant species richness and cover, invertebrate species richness and abundance, and bird species richness and activities. A management program, proposed by Zentner & Zentner (1988) includes: 1) formation of a maintenance district; 2) listing of restoration success objectives, particularly the acceptable minimum standards for successful wetland restoration; and 3) establishment of involved party interactions throughout the project including the five year monitoring program and any corrective measures for unsuccessful restoration efforts at the end of the five year program.

Initial results (May 1988) for the Laguna Creek project, which was initiated in 1988, demonstrate that: 1) 47 plant species including many vernal pool species have colonized soils of at least one created pool; and 2) total absolute plant cover ranged from 20-65% along 13 belt transects through this pool (Jokerst 1988). The plan proposed by Zentner & Zentner (1988) and assisted by the staff of the U. S. Fish and Wildlife Service, the Environmental Protection Agency, and the U. S. Army Corps of Engineers has one of the most thoroughly documented preproject plans in Central California. It contains many of the objectives and analyses that we believe should result in a successful post-project monitoring program and perhaps a successful long-term vernal pool creative effort.

Southern California (Santa Barbara County)

Coal Oil Point Reserve. A vernal pool creation project was funded ($15,000) by the University of California, Santa Barbara, as an "unofficial" mitigation for destruction of natural vernal pools that occurred when a faculty housing project was constructed on West Campus (Pritchett 1986a, b). A group of fifteen potentially interconnected pools were constructed in introduced annual grassland at Coal Oil Point Reserve, which is part of the University of California Natural Reserve System. The pools cover 6450 square feet and have a maximum relief of

nearly 3.5 ft (Pritchett 1986a). A private contractor was hired to excavate the pools in a shallow drainage trough on a coastal terrace that is part of a group of terraces supporting the only natural vernal pools in the Santa Barbara region (including those at Del Sol Reserve). Preproject and post-project topographic maps were produced; soil samples were analyzed for clay content; and seed bank material obtained from a natural vernal pool was distributed sparcely in half of the excavated depressions.

Results of the first period (January-May 1987) of post-construction monitoring revealed that, although 15 pools resulted from the first rainfall, subsequent storms produced enough rainfall to temporarily connect all pools into a single pond approaching 30 inches deep (Pritchett 1986a). Because of the greater depth and longer duration of flooding, physical conditions and vegetation of the deepest portions of the combined pools are more characteristic of freshwater marsh habitats; however, because of the shallower depth and shorter duration of flooding, physical conditions and vegetation on the periphery are more characteristic of vernal pool habitats.

Results of the second period (January - May 1988) of monitoring revealed that lower rainfall and greater distances between storms produced fewer connections between pools and, thus, established more wetland that was shallower and flooded for a shorter duration than had occurred in the first year (Pritchett, unpubl. data). Nine native vernal pool species occurred at the site in 1987 and 1988.

The artificial topography and unnatural flooding patterns of these pools may result in the establishment of more freshwater marsh than vernal pool habitat. Future manipulation of the project design, such as installing a culvert through the berms, might be necessary if the management committees determine that additional vernal pool habitat is desirable.

The project at Coal Oil Point Reserve was our first effort to create vernal pool habitat. Results of this project helped us design

and implement the Del Sol Vernal Pool Enhancement Plan, particularly with regard to size and depth of pools, size of watershed for pools, and use of seed bank material.

Southern California (San Diego County)

Miramar Road. In 1981, a project was initiated to "rehabilitate" degraded vernal pools on Miramar Road in the City of San Diego (Scheidlinger et al. 1984, Zedler and Black 1988). Vernal pools were disturbed or nearly destroyed when the site was cleared and disced by a developer without the required permits (Scheidlinger et al. 1984). Settlement of a law suit against the developer included the establishment of a fenced reserve at the disturbed vernal pool site. The rehabilitation plan described by Scheidlinger et al. (1984) included an experimental approach, whereby three pools of five various treatments were evaluated for physical and biological attributes. The treatments included: 1) disturbed pools; 2) reconstructed pools; 3) reconstructed pools inoculated with seed bank material; 4) disturbed pools inoculated with seed bank material; and 5) natural pools from a different reserve. Six basins were re-created (i.e., excavated), three of which were left without inoculum; another six were left in their severely degraded state. Although this project is largely a restoration effort, the re-excavation of basins is similar to a habitat creation project and is similar to both restoration and creation efforts at Del Sol Reserve in Isla Vista.

Scheidlinger et al. (1984) states that, "While some conclusions can be drawn from a strict comparison of experimental treatments much of the interpretations of the data depends on the incorporation of data describing individual differences within and between pool sets that cannot easily be summarized strictly in terms of the experimental design." They did find, however, that excavation of basins was an effective means of restoring more natural depth and duration of flooding in a vernal pool habitat. They report that: 1) long or short extremes of flooding duration were disadvantageous for the development of vernal pool flora; 2) inoculation of vernal pools with seed bank material had a

dramatic effect in cover, although species richness between seeded and unseeded pools was not great; 3) although excavated and inoculated pools had some problems with depth and turbidity, certain areas of these pools had a flora indistinguishable from that in natural pools only three years after the restoration efforts; 4) particular sensitive plant species (e.g. Pogogyne abramsii) can be introduced successfully where suitable habitat has been created; and 5) the introduction of inoculum, at sites where a natural topography had been established, greatly accelerated the establishment of a vernal pool community. They conclude, however, that "...the degree of resilience of the system following disturbance, without any intervention, is quite high", and that "...certain interventions can be highly effective: 1) providing a more natural water regime that presumably will allow for more long-term stability of the recovering plant community, and 2) in increasing the rates at which disturbed habitat can be occupied."

After seven growing seasons following the rehabilitation effort at Miramar Road, post-project monitoring studies by San Diego State University (SDSU) continue to evaluate the recovery of the flora and vegetation. Zedler and Black (1988) discuss the preliminary results of C. Patterson, a student at SDSU, and state that, "...the three inoculated pools, which happen also to have the most favorable water duration characteristics, are good approximations of natural pools...[and have] a normal complement of vernal pool species (Patterson, unpublished). Therefore, he considers that this creation/rehabilitation effort, at least for half of the created basins, has been successful."

The Miramar Road project was one of the first large vernal pool restoration and creation projects in California implemented to mitigate a specific loss. The post-project monitoring program is one of the more useful long-term efforts from which we can estimate success of such activities. Results from this SDSU research suggest that there is a good probability of long-term success for at least portions of the Del Sol project, particularly for vernal pool establishment in the inoculated created basins.

Interstate 15, Miramar Naval Air Station. In fall 1983, ten basins were excavated by CALTRANS in the right-of-way west of Interstate 15. In fall 1984, soil and plant material salvaged from pools destroyed by the construction of I-15 were deposited in eight of the ten basins as an experimental approach to the creation of vernal pool habitat and to the establishment of Pogogyne abramsii, a federally listed endangered plant (Scheidlinger 1985, Scheidlinger 1988, Zedler and Black 1988). The donor pools were evaluated floristically, but no soil cores or soil analyses were conducted at the creation site prior to excavation of the basins (Scheidlinger 1985). Ponding of water in nearby basins, however, suggested that establishment of appropriate hydrological conditions in the new basins was probable. Post-construction monitoring recorded: 1) topography; 2) duration of flooding; 3) composition of basin floras; 4) total plant cover; and 5) plant species distribution within pools (Scheidlinger 1985).

After two growing seasons following inoculation with seed bank material, Scheidlinger (1985) found that: 1) duration of flooding in the artificial pools was not different from the natural pools of the region; 2) the new basins contained a much greater number of non-pool upland plants (mostly exotics) than the surrounding chaparral vegetation; 3) total plant cover in the two uninoculated basins was less than 20%, and only 22% of this cover was accounted for by species "typical of vernal pools"; 4) total plant cover in the eight inoculated basins ranged 21.6-75.8% with mean total cover at 44%, and 54% of this cover was accounted for by vernal pool species; 5) total plant cover in natural pools was 89%, and 88% of which was accounted for by vernal pool species; 6) Pogogyne abramsii appeared in all inoculated pools; 7) at least some species are distributed differently within the artificial basins as compared with natural vernal pools; and 8) some species from deeper pools with longer flooding durations were absent from the artificial pools.

In a summary of results subsequent to Scheidlinger's initial study, Zedler and Black (1988) refer to Scheidlinger's (1988) recent

report that only five of the ten artificial basins now have hydrologic characteristics of vernal pools and two of these are the uninoculated pools that support few vernal pool species. Of the three hydrologically suitable inoculated pools, she reports only one has developed a "vigorous" vernal pool flora that includes a large population of the endangered Pogogyne abramsii.

The potentially low success rate of the Interstate 15 project (12.5%, Scheidlinger 1988) based on results after four years following inoculation, suggests that it may be too soon to predict the long-term persistence of created vernal pools at Del Sol Reserve. Because initial results of monitoring for the I-15 project were more optimistic for success than later results, our interpretations of Del Sol monitoring must be considered tentative.

Miramar Landfill. Naturally-occurring vernal pools at this site were disturbed for agricultural purposes approximately 75 years ago (Zedler 1986). In a review of projects for CALTRANS, Zedler (1986) stated that the mounds associated with pools no longer exist and that the depressions "...drain more quickly than do undisturbed pools, and during dry years they do not fill at all." He reports unpublished data that reveal 1) in dry years exotic annual plants (e.g., Hypochoeris, Erodium, Bromus) occur more frequently (50%) in the disturbed pools than in undisturbed pools in the same region; 2) in dry years the native and endangered plant Pogogyne abramsii occurs less frequently in disturbed pools than in undisturbed pools; and 3) the vernal pool species Dowingia cuspidata occurred only in pools with standing water. Zedler concludes that, "Even allowing for the damping effect of seed banks, it is clear that population fluctuations are greater in the disturbed pools and that dry years result in declines in vernal pool species and greater frequency of occurrence of upland exotics in the pool basins."

In this situation, long-term unassisted recovery following disturbance has not resulted in pools with fully natural features. The observations reported by Zedler are similar to ones for Del Sol Reserve. At the Reserve, artificial draining of a pool apparently resulted in

reduced flooding and an increase in exotic species, particularly Lolium multiflorum.

Del Mar Mesa. In recent years, highway projects in San Diego County have occurred in areas that support native vernal pools. To partially mitigate the loss of vernal pool habitat for the endangered species Pogogyne abramsii, CALTRANS acquired property on Del Mar Mesa to be used in an experiment to create vernal pools that could support P. abramsii (Zedler and Black, 1988). The Zedler team from SDSU was hired to help design, construct, and monitor the project (Zedler 1986, Zedler and Scheidlinger 1986). Forty artificial basins were excavated in 1986, 37 of which were inoculated with seed bank material combined from several natural vernal pools and three of which were not inoculated for comparison. Zedler et al. conducted a post-construction study to compare created pools with six natural pools on Del Mar Mesa. They evaluated the total species number, species within ponds along elevational gradients, and the establishment and reproduction of P. abramsii (Zedler and Black 1988).

After two years of study, Zedler and Black (1988) found that most of the excavated basins held water as long or longer than the natural pools and conclude that "...excessive water duration may be a problem in establishing vernal pool biotas." This is the same problem Pritchett (1986a, 1986b) encountered with the project at Coal Oil Point Reserve. Regarding the vernal pool flora, Zedler and Black found "a representative assemblage of vernal pool plants" in the artificial pools and that some species were more frequent in the created pools than in the natural ones. This result is similar to that from the Del Sol project in which we found several species to be more abundant in the created pools than in natural pools. However, as at Del Sol, Zedler and Black also found that after two years the artificial pools on the Del Mar Mesa had less plant cover (ca. one half) and more area of bare ground (over twice) than did the natural vernal pools. They observed some pools with low vegetative cover and with no cover, and concluded that "...even the most optimistic extrapolation from present conditions suggests that no more than 75% of the pool basins will evolve into

replicas of natural pools". In regard to the response of Pogogyne abramsii, Zedler and Black (1988) concluded that survival to maturity and flowering of plants in artificial pools was low, even though recruitment was good, and that a prediction on the long-term success of establishing populations of P. abramsii is difficult to make. In a general analysis of their project after two years, they conclude that only a few created pools approximate natural ones in plant species composition and density, but that there may be hope for improvement because: 1) inoculation was low and populations have not reached potential sizes; 2) rainfall was not conducive to optimum expansion of vernal pool plant populations; and 3) additional manipulations of the excavated basins may improve those habitats that were vegetated less successfully in the initial experiment. All of these points are equally valid for the project at Del Sol Reserve.

Miramar Naval Air Station. The most recent vernal pool restoration/creation project in San Diego County was initiated in fall 1988 when 22 basins were excavated on Miramar Naval Air Station to mitigate loss of pools resulting from activities on the military base (Zedler, pers. comm., 1988). Zedler et al. from SDSU have assisted with the experimental design of the project, which will include inoculated and uninoculated pools and reference natural pools. Data from spring 1989 will provide the first results of this project.

Summary of Projects

At least 16 vernal pool projects or related activities have been proposed or implemented in California. Enhancements include: 1) fencing for protection of pools that resulted in unassisted recovery of disturbed areas at Phoenix Park Ecological Reserve; and 2) installation of barrier posts for habitat protection and elimination of artificial drainages that altered the hydrology of pools at Del Sol Reserve. In a related situation, disturbed pools recovered after abandonment of agricultural activities at the Miramar Landfill site. Restorations include: 1) excavation of degraded pools, with and without introduction of seed bank material, at Miramar Road for mitigation of

disturbances to vernal pools and impacts to endangered species; and 2) excavation of degraded vernal pools at Del Sol Reserve with largely an unassisted recovery of vegetation.

Habitat creation projects include: 1) use of artificial impervious substrates (plastic or cement) in excavated basins, followed by inoculation with seed bank material or seeds of selected species at Fair Oaks and UC Berkeley; 2) use of enhanced impervious substrates (addition of bentonite to subsoil) and relocated topsoil with seed bank material at Davis Interchange for an aesthetically-oriented project; 3) unintentional creation of vernal pool habitat in borrow pits near natural vernal pools at Myres Ranch; 4) excavation of pools in old sewage treatment settling ponds at Davis Audubon Reserve; 5) excavation of basins at Del Sol Reserve, with an experimental revegetation program, to mitigate historic loss of vernal pools in the Santa Barbara region; 6) experimental projects for endangered species as part of the mitigation for developments at Rancho Buena Vista, Interstate 15, Del Mar Mesa, and Miramar N.A.S.; 7) pre-mitigation experimental creation of vernal pools at Laguna Creek; and 8) creation of new habitat at Folsom, Laguna Creek, Coal Oil Point Reserve, Interstate 15, Del Mar Mesa, and Miramar N.A.S. to mitigate impacts from various types of land development. Some of the latter projects include experimental revegetation programs in which pools inoculated with seed bank material are compared with both uninoculated created pools and natural pools to evaluate the success of habitat creation.

Results of the various habitat manipulations are mixed: short-term evaluations range from qualified successes to uncertainties or failures; long-term observations and predictions range from successful to uncertain. Because many projects have lacked "performance criteria" before the construction of the pools began, evaluation of post-project results in terms of success may be unfeasible. Comparison of manipulated (e.g., restored or created) sites and natural sites, however, has been a useful method to estimate the status of habitat recovery or establishment. But the lack of detailed knowledge of physical and biological attributes of natural reference pools, whether

existing or destroyed, can make evaluation of the manipulated pools quite difficult because no accurate model of the natural ecosystem exists.

CONCLUSIONS

Conclusions regarding the manipulations of the claypan, coastal mesa type of vernal pools in the Santa Barbara region may not be applicable to vernal pools of other regions or with different origins and physical features. Enhancement, restoration, and creation of vernal pools at Del Sol Reserve occurred within or adjacent to natural pools or at sites nearby existing pools that had natural clay subsoils. Our task to create vernal pools undoubtedly was made considerably easier than it might have been if we attempted to create vernal pools in a region where pools are not known to have occurred naturally.

Enhancements. Removal of refuse not only improved the aesthetic value of the Reserve, but also improved habitat values. The barrier constructed on the perimeter of the Reserve eliminated unauthorized vehicle access. The usefulness of the three dams, however, is not known at this time because there has been two seasons of inadequate rainfall following construction; thus, there has been no obvious increase in the extent or duration of flooding in the pools. Subsequent years of regionally average rainfall and rainfall patterns and additional post-project monitoring are expected to reveal increased flooding and a shift from dominance by naturalized grasses to dominance by native vernal pool species. We postpone conclusions on the success of this activity until the required fifth year of monitoring has been analyzed.

Restored Pools. Removal of soil piles and excavation of some areas increased wetland habitat. Because an ambitious revegetation program was not implemented, and because we anticipate existing seed bank will contribute to the recovery process, revegetation by native vernal pool species is predictably slow. Vernal pool species do occur, however, and we predict that with several years of average rainfall restoration will have produced a measurable improvement in vernal pool

habitat based on presence, cover, and abundance of native vernal pool plant species. We postpone conclusions on the success of this activity until the required fifth year of monitoring has been analyzed.

Created Pools. The most striking effects of the Enhancement Plan occurred at the site where pools were created. Those pools inoculated with seed bank had a remarkable response to rainfall, resulting in habitat suitable for native species, including vernal pool endemics. Those without inoculum demonstrated a predictably weaker response during two years of monitoring, although a few individual vernal pool plants were present. We conclude that excavation of depressions at sites with a clay subsoil and subsequent adding of seed bank material from existing vernal pools can result in the short-term creation of new vernal pool habitat. The longevity of such new habitats, however, may not be predictable without extended monitoring. Therefore, we postpone predictions on the probability of long-term success of created vernal pool ecosystems until additional monitoring of vernal pool organisms, water chemistry, and other attributes reveals that the new pools function at some acceptable level similar to pristine natural vernal pools.

R E C O M M E N D A T I O N S

Based on the results of the monitoring program for this project, we provide the following recommendations for future activities at Del Sol Reserve and for manipulations of vernal pool habitats in general.

Del Sol Reserve. Several future enhancements or restorations should be considered for the Reserve (Fig. 45).

1. Because of the potential success of the manipulations of wetland, particularly the creation of pools, we recommend that, following successful results of the fifth year of monitoring restored pools, the existing degraded vernal pool in the north-central part of the Reserve (Fig. 15) be restored (Fig. 45, "wetland"). This could be accomplished by excavating and recontouring the basin and by adding

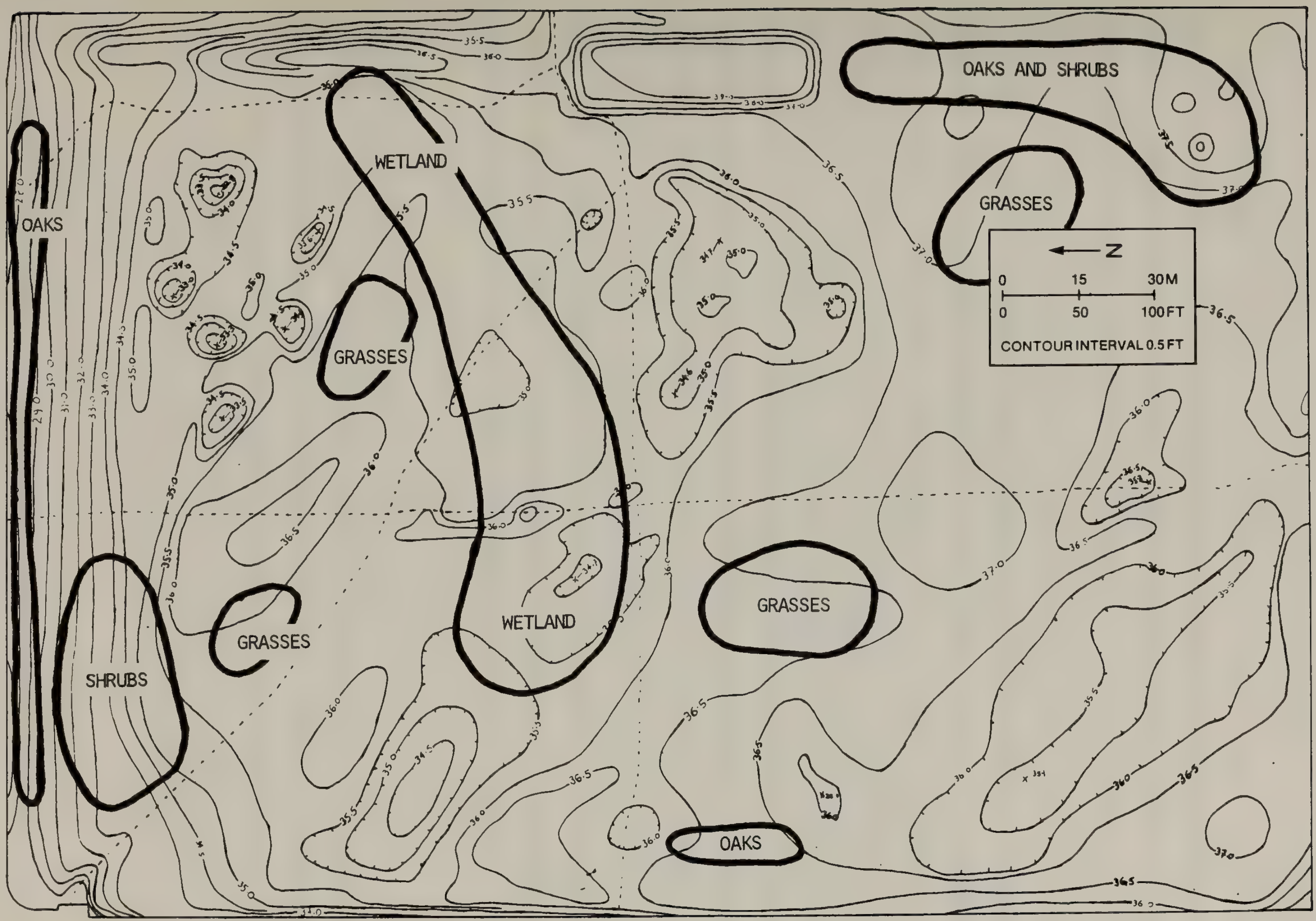

Fig. 45. POTENTIAL AREAS FOR FUTURE RESTORATION AT DEL SOL RESERVE. Labels denote the type of activity at each area.

sufficient seed bank to initiate successful revegetation of the site. A deeper wetland than the existing one should provide more habitat favorable to native vernal pool species. We do not recommend that additional vernal pools be created at Del Sol Reserve, but rather that various wetlands and uplands should be enhanced and restored to increase the plant and wildlife (e.g., Brush Rabbit, California Quail) habitat values of the site.

2. We recommend that native grasslands be restored to sites presently dominated by naturalized annual grasses (e.g., Fig. 45, "grasses"). Hordeum californicum (California Barley) still persists along paths at the Reserve and could be one species used in the effort. Stipa pulchra (Purple Needlegrass) dominates portions of Ellwood Mesa and Bromus carinatus (California Brome) is locally common at More Mesa. Both of these species could be introduced to Del Sol Reserve, where they probably grew prior to disturbances caused by agricultural development earlier in this century. Various native forbs also could be added to the revegetation plan for the grassland. In addition to those already present, Orthocarpus densiflorus (Owl's Clover) and Lupinus succulentus (Succulent Lupine) are examples of local species that could be added to the Reserve. Additional populations of Asclepias fascicularis also could be added to expand the food source for caterpillars of Monarch Butterflies that have a regionally significant winter roosting site about 2 km west of the Reserve.

3. We recommend that native shrubs, particularly Baccharis pilularis ssp. consanguinea (Coyote Brush), and oak trees Quercus agrifolia (Coast Live Oak) be included in an upland enhancement plan associated with the grassland restoration (Fig. 45, "oaks" and "shrubs"). These species should increase the wildlife (e.g. Acorn Woodpecker) habitat values of the Reserve and are expected to survive because both species occur in the area naturally.

4. We recommend that additional post-project monitoring should occur where wetlands were manipulated to determine the effectiveness of the Enhancement Plan five and ten years beyond the construction phase of

the project that ended in 1986. The Coastal Commission Consistency Permit (CCC 1986a) requires that monitoring occur the fifth year after construction and that a report be prepared on the results.

5. We recommend that "thatch", an accumulation of organic matter from invasive weeds, be removed from the enhanced pool (Pool N) if the change in hydrology alone does not produce an increase in abundances of native vernal pool species. The exposed substrate after removal of thatch and adequate flooding may provide favorable conditions for native hydrophytes. Fire should be considered as an alternative to physical removal of the accumulated material.

6. We recommend that Del Sol Reserve be considered a local refugium for regionally rare and/or endangered vernal pool species (e.g., Eryngium armatum, Lasthenia conjugens) known to occur or that have occurred in the Santa Barbara region. Although some of these species may never have occurred in what is now the Reserve, the pools at Ellwood Mesa, West Campus, Isla Vista Mesa, and More Mesa should be considered collectively as a single complex of pools rather than individual groups of pools. All types of local vernal pool habitats, however, do not occur at Del Sol Reserve. Thus, some regionally rare species not presently growing in the Reserve may not persist if introduced there because current habitat conditions may not support them. Because virtually all other sites in the Santa Barbara region that contain vernal pools are owned privately and are potential areas for residential development, we recommend that Del Sol Reserve be considered as the regional site to preserve local genotypes of the remaining regionally rare species. Preferably, however, the Santa Barbara region should have several vernal pool reserves, at least one reserve located in each area (More Mesa, Isla Vista, Ellwood Mesa, West Campus) where pools occur naturally. The desirable result of this action might be the preservation of the naturally occurring richness of vernal pool habitats and species.

7. We recommend that the Isla Vista Recreation and Park District aggressively pursue the maintenance program at Del Sol Reserve. This

should include repairs of the barrier when necessary, removal of refuse on a regular basis, and replacement of interpretive signs when they decay or are damaged, and discouraging footpaths from crossing more pools than they already do, including a path through Pool E that developed during the summer of 1987. The District also should continue to pursue its public awareness program to increase interest in the Reserve and in the valuable natural resources preserved within its boundaries.

General recommendations. Although it may be difficult to apply the findings of this study to other regions, we believe several general recommendations are realistic and appropriate.

1. We recommend that all projects regarding enhancement, restoration, or creation of vernal pools include comprehensive preproject and post-project monitoring plans. Preproject plans should provide enough evaluation of the physical environment to suggest that a project is feasible; post-project monitoring should include aspects of both the physical environment and the biological resources and should be of sufficient duration to demonstrate the long-term viability of the manipulated wetlands. To evaluate the success of mitigation projects, "performance criteria" should be established before each project begins so that results of post-project monitoring can be reviewed according to standards of success. Although the Del Sol Vernal Pool Enhancement Plan included monitoring, additional plant species could have been included in the quantitative analyses, invertebrate animals could have been included in a more thorough approach, performance criteria could have been established, and continuation of the monitoring program could have been funded for at least five years rather than funded for only two years. Nonetheless, the Coastal Commission Consistency Permit does require a fifth year of monitoring.

2. Projects involving the enhancement, restoration, or creation of vernal pools should consider the following technical variables (in no particular order) and how they might affect results: 1) protection of the site from disturbances; 2) proximity to or sympatry with the

historic range of natural vernal pools; 3) invasion by weeds; 4) penetration of the impermeable layer in the pool substrate; 5) size of pool watershed; 6) depth of pools and potential duration of flooding; 7) water chemistry; 8) potential for natural dispersal of organisms; 9) source, quality, and quantity of seed bank material and invertebrate inoculum; 10) degradation of seed bank donor pools; 11) maneuverability and precision of excavating equipment; 12) feasibility of site for long-term protection and maintenance.

3. We recommend that regional planners, politicians, and environmental consultants not interpret the apparent short-term success of the creation of vernal pools at Del Sol Reserve as a "green light" to mitigate the loss of natural vernal pools (i.e., those destroyed because of development) by proposing the creation of vernal pools elsewhere. The few remaining examples of natural vernal pool groups in California must be preserved to provide habitats for regional genotypes of widespread, but habitat-restricted species, and for local vernal pool endemics. Artificial vernal pool habitats have not been demonstrated to support native vernal pool species nor to function like natural vernal pools for extended periods of time. We recommend that creation of vernal pools should not be incorporated into the permitting process for development in environmentally sensitive habitats until additional analysis reveals the likelihood of long-term success.

4. We recommend that examples of the various regional groups of California vernal pools should be acquired for public ownership and subsequently enhanced or restored as each situation may require. Creation of vernal pools in these regional groups should be considered only as a method to expand remnant vernal pool groups to compensate for the historic loss of habitat.

5. We recommend that interpretive signs, literature, or other public information techniques should accompany vernal pool reserves to increase public awareness of the uniqueness and value of these natural resources.

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APPENDIX I.

DEL SOL VERNAL POOLS ENHANCEMENT PLAN

Reproduced from State Coastal Conservancy (1986)

Introduction

Vernal pools are a unique habitat type occurring where restricted drainage, a Mediterranean climate and flat, undrained topography combine to allow the formation of freshwater pools in the wet season which slowly evaporate as summer approaches. Vernal pools display several unusual characteristics. Plants inhabiting vernal pools must tolerate seed germination and seedling growth in standing water while the mature plants grow in very dry soil conditions. Few plants can tolerate these conditions. Thus, vernal pools create highly specific plant associations not easily replaced by other species. Many rare plant species are found in vernal pools, several of which are listed by the State of California as endangered.

"Vernal" refers to spring when the various plants inhabiting the pools may undergo a brief flowering period, sometimes creating spectacular rings of color for a few short weeks. Distinct zonations occur in concentric circles, even though the pools are very shallow with gradual slopes.

Due to their location on flat, hence developable, land, the number of sites supporting vernal pools in California has dwindled, particularly in the southern half of the state where they were historically rare to begin with. At present, in Southern California vernal pools exist only in Riverside, San Diego, and Santa Barbara Counties.

In Santa Barbara County, several sites support vernal pools, but only one may have the potential for long-term preservation. There are the Del Sol pools in Isla Vista. The six Del Sol pools range in size from one-quarter to one acre and are located on 11.45 acres of land owned by the Isla Vista Recreation and Park District. The few other remaining vernal pools in Santa Barbara County are privately owned and exist in a generally deteriorated condition due to poor management.

Site Description

The Del Sol pools are located in the center of Isla Vista, an unincorporated community in Santa Barbara County. Isla Vista is directly adjacent to the University of California. Over 50% of the community's 17,000 residents are students. Prior to the 1960's, Isla Vista contained a fairly pristine collection of vernal pools. During the 1960's, many large apartment complexes were constructed to house the increasing student population. Most vernal pools were obliterated, and those remaining were subjected to mosquito abatement activities, including spraying with insecticides, draining and fill.

In 1978, the Isla Vista Recreation and Park District purchased the 11.45 acres containing the Del Sol pools for $138,102 to protect the site from encroaching development. In 1981, the District attempted to purchase the other remaining site in Isla Vista containing vernal pools but the landowner refused to sell at the appraised value. The vernal pools on this site have since deteriorated.

The Del Sol pools support a number of plant species of special interest including several which are restricted to vernal pool type habitat: *Pilularia americana* and *Eryngium armatum*. Other plants of concern include

Alopercurus howellii, Anagallis minimus, Brodiaea jolonensis, Elatine brachysperma, Crassula aquatica and Phalaris lemonii. When filled with water, the pools attract water-associated birds, including egrets and ducks, and provide habitat for several small mammals and amphibians.

Because the property supporting the Del Sol pools gives the appearance of unused, undeveloped land, it has been plagued with illegal dumping brought about by unimpeded vehicle access and lack of awareness of area residents of the value of vernal pools. The enhancement plan detailed below addresses these issues and is aimed at preserving and expanding the Del Sol pools to provide an unique educational opportunity for natural history enthusiasts as well as serious students of botany and biology.

ENHANCEMENT PLAN

A grant will be provided to the Isla Vista Park and Recreation District to implement the plan (See Attachment 1, Enhancement Plan Map). The District will work closely with the University of California Santa Barbara Herbarium Environmental Research Team to direct the project. The Research Team has conducted extensive field analysis of the Del Sol Vernal Pools and is an excellent position to provide the necessary technical expertise to ensure maximum benefits.

1. Removal of fill and debris:

Through the years the property on which the Del Sol pools are located has been subjected to much illegal dumping. The site is littered with fill, broken concrete, old appliances, abandoned furniture and other debris. One section contains an abandoned parking area, illegally paved some years ago. All of the above material will be removed from the site which should allow the natural expansion of pools in some areas.

2. Enhancement to expand existing vernal pools

As per the attached enhancement map, several pools would be expanded to provide additional habitat. Site 1 is dominated largely by non-native grasses and would be excavated to a lower depth to retain more water and provide habitat for native plants. Site 2 would be improved through the removal of spoil piles from within its historic boundaries and clearing exotic vegetation from its margins (Site 3). Site 5, the largest pool, contains the greatest collection of native flora, but is increasingly threatened with non-native grasses. At this location, the construction of two low berms will prevent rapid drainage, thus retaining more water in the wetland making it more suitable for various native species.

3. Creation of additional vernal pool habitats:

A previous project conducted by the University of California has demonstrated that artificial contouring of an area can produce depressions that will hold precipitation, resulting in habitats that are similar to native vernal wetlands. Because of the significant losses on the Del Sol site through the years, additional pool habitat would be created to compensate for past loss (Site 4). The site would be recontoured to

produce a complex of small pools of various sizes and depths to provide a maximum of microhabitat types.

4. Placement of barrier:

The site has been left unprotected since acquired by the Park District due to lack of funds. Vehicles are able to drive onto the property without impediment creating easy access for illegal dumping. The project would fund the placement of a low visibility barrier of 2-1/2' posts at 4' intervals around the perimeter of the property to prevent vehicle access without blocking pedestrian access. Existing pedestrian trails will remain. The prevention of vehicles from entering the site should also allow the expansion and enlargement of existing pools.

5. Installation of information signs:

In addition to unimpeded vehicle access, one of the major reasons the site is abused is the lack of awareness on the part of the public of the existence and value of the pools. During much of the year, the pools are difficult to identify without some knowledge of the type of plant species that grow within them. The installation of informational signs will identify the vernal pools, briefly describe their value, and route visitors around them.

6. Installation of refuse containers and a seating area:

The site presently contains no refuse containers or seating area. The installation of these elements will allow easier maintenance of the site by the Park District and will provide added amenities for visitors.

7. Publication of a layperson's guide to vernal pools

As mentioned above, lack of knowledge about vernal pools has lead to their abuse. With the assistance of the University of California, the Park District has accumulated much information about vernal pools, but will need to conduct additional research to complete the data. The project will fund the completion of research and the publication of data in non-technical language with illustrations in guidebook form for use by residents and visitors to Isla Vista. The publication will be available at the Isla Vista Recreation and Park District office located several blocks from the Del Sol site.

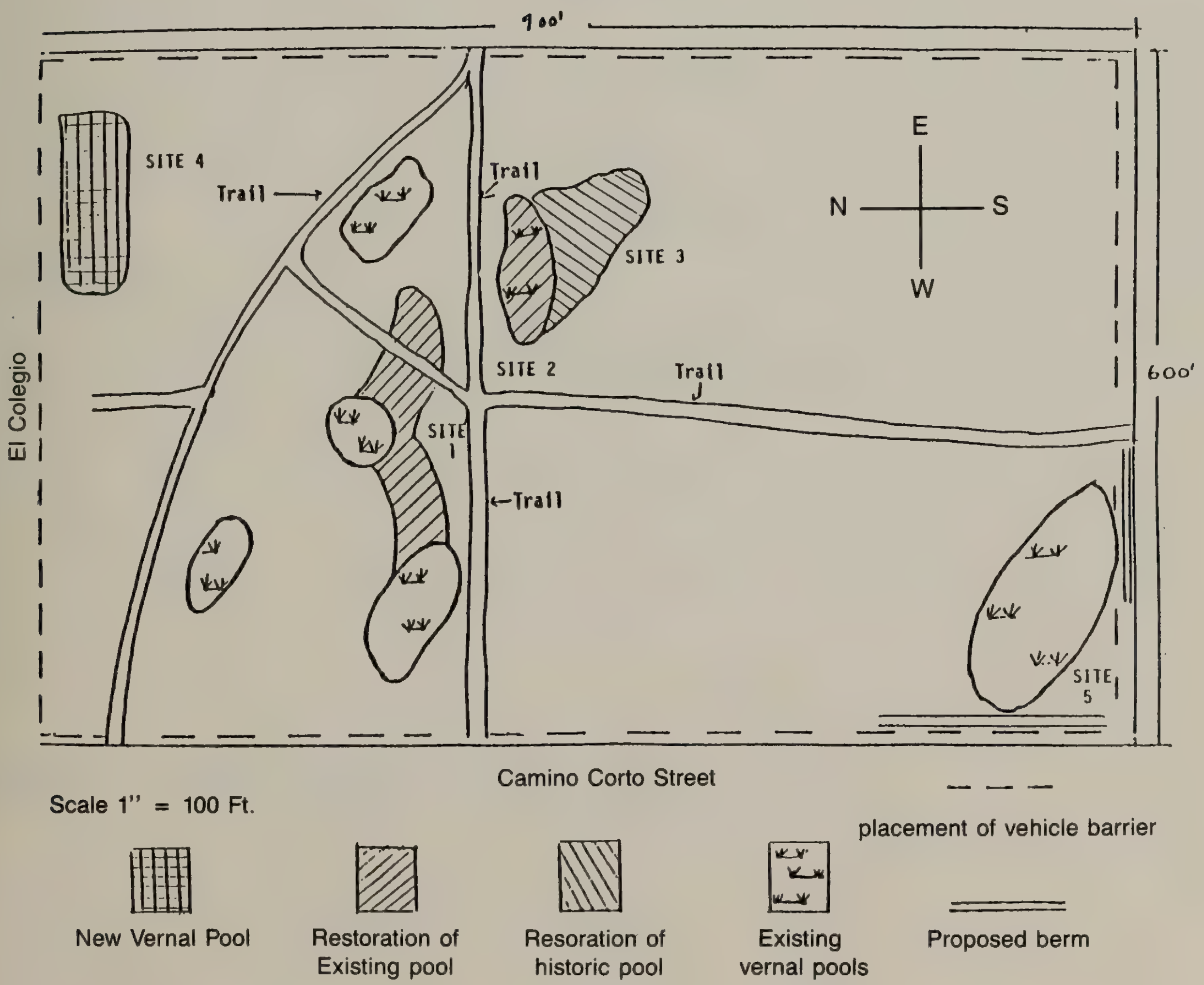
8. Project Monitoring:

Project Monitoring will occur over one year and will include the presentation of a detailed topographic map of the entire Del Sol site, the plotting of regionally rare plant locations, the evaluation of water levels and analysis of vegetation response to site alterations.

The Park District has contracted with the California Conservation Corps to supply much of the labor required to complete the project. With the proposed improvements in place, the Park District will be able to more efficiently manage the site for resource protection while providing a

valuable educational and recreational experience for residents, students at the University of California and visitors to Isla Vista.

ENHANCEMENT MAP
Attachment 1



APPENDIX II

CATALOGUE OF THE VASCULAR PLANTS OF THE DEL SOL OPEN SPACE AND VERNAL POOL RESERVE SANTA BARBARA COUNTY, CALIFORNIA

Compiled by

Holly C. Forbes[1]

UCSB Herbarium
Department of Biological Sciences
University of California, Santa Barbara

[1] Current Address: University Botanical Garden,
University of California, Berkeley, CA 94720

INTRODUCTION

The vernal pools on the Del Sol site, the property southeast of the intersection of El Colegio Road and Camino Corto in Isla Vista known as the Del Sol Open Space and Vernal Pools Reserve, are the subject of a restoration project being conducted through the Herbarium of the University of California at Santa Barbara (UCSB). To aid in this restoration, a collection of voucher specimens was made in 1987 from the Del Sol pools. In addition, a search for native vernal pool species preserved in the Herbaria of UCSB and the Santa Barbara Botanic Garden (SBBG) was made to ascertain as much as possible the historical presence/occurrence of vernal pool species in this area. Information obtained through these two avenues is here compiled in an annotated catalogue.

This catalogue includes all native and naturalized vascular plants that were collected or observed during this study, collected or observed by others during concurrent or previous studies, or reported in the literature from Del Sol Reserve and vicinity. The catalogue is arranged according to a phylogenetic arrangement of ferns, gymnosperms, and angiosperms, and within the latter by dicotyledons and monocotyledons. The families, genera, and species are listed in alphabetical order within each group.

The information given for each plant may include the following: scientific name, common name (if one exists), habit (annual, perennial herb, shrub, tree), local abundance (relative number of plants at any one site), approximate position in the vernal pools, "introduced" if it is not native to the area, and collection number(s) of H. C. Forbes from 1987 (specimens deposited at UCSB Herbarium). The abbreviation used for the Forbes collections is defined as follows: DS is the Del Sol site, numbers in () indicate the pool on the site from which the collection was made. This list is followed by a list of specimens at the UCSB and SBBG Herbaria and any listed in the Henry M. Pollard card file (located at SBBG).

Although most of the nomenclature is consistent with Munz (1959, 1968, 1974), other names have been applied to some plants more recently, in which case synonyms may also be listed.

DIVISION TRACHEOPHYTA

SUBDIVISION PTEROPSIDA

CLASS FILICAE

MARSILEACEAE Marsilea Family

Pilularia americana A. Braun. Pillwort. Perennial fern; locally common in wet years.
UCSB: Del Sol site, northeast corner of lot, 20 Apr 1981, *G. Kuenster 177*; Del Sol site, 21 May 1978, *S. J. Katz 7*; Del Sol site, northeast of Camino Corto and Abrego Road, 24 Apr 1974, *R. Broder, s.n.*

CLASS ANGIOSPERMAE

SUBCLASS DICOTYLEDONEAE

AIZOACEAE Carpet Weed Family

Carpobrotus edulis (L.) Bolus. Hottentot-Fig. Prostrate succulent shrub; rare; margin of pools; introduced; *DS 1293(11)*.

APIACEAE Celery Family

Eryngium vaseyi Coulter & Rose. Coyote Thistle. Perennial herb; common; center of pools; *DS 1125*.
UCSB: Camino Corto and Abrego, 9 May 1981, *Kuenster 184*; Camino Corto and Abrego, 20 May 1967, *Keefe 1752*; Vernal pool in Isla Vista, 31 May 1962, *Breedlove 2886*; Vernal flats in fields of Isla Vista Tract, 6 May 1956, *C. F. Smith 4460*.
SBBG: Vernal flats of Isla Vista Tract, 15 June 1950, *C. F. Smith 2804*; Vernal flats of Isla Vista Tract, 20 Apr 1950, *C. F. Smith 2658*; Vernal flats of Isla Vista Tract, 9 Oct 1947, *C. F. Smith 2152*.

Foeniculum vulgare Mill. Sweet Fennel. Perennial herb; common; grassland adjacent to pools; introduced; *DS 1271*.

ASCLEPIADACEAE Milkweed Family

Asclepias fascicularis Dcne. in A. DC. Narrowleaf Milkweed. Perennial herb; locally common; grassland adjacent to pools; *DS 1272*.

ASTERACEAE Sunflower Family

Ambrosia psilostachya DC. var. californica (Rydb.) Blake. Western Ragweed. Perennial herb; common; grassland and margins of pools; *DS 1343*.

Baccharis pilularis DC. subsp. consanguinea (DC.) C. B. Wolf. Coyote Bush. Shrub; locally common; grassland; *DS 1273*.

Carduus pycnocephalus L. Italian Thistle. Annual; rare; grassland and disturbed sites; introduced; *DS 1315*.

Conyza canadensis (L.) Cronq. Horseweed. Annual; locally scattered; pool margins and adjacent grassland; *DS 1347*.

Cotula coronopifolia L. Brass Buttons. Perennial herb; uncommon to common; center of pools; introduced; *DS 1138(10)*.

Gnaphalium californicum DC. Green Everlasting. Biennial; not in pools; rare near pools but common elsewhere; *DS 1278*.

Grindelia robusta Nutt. Gumplant. Perennial herb; locally common; margins of pools and along footpaths; *DS 1296*.

Hemizonia australis (Keck) Keck. Spikeweed. Annual; locally common to rare [CNPS List 3], reaching the northern limit of its distribution; center to margins of desiccated pools; *DS 1294(11)*.
SBBG: East of Isla Vista School, 15 Sep 1964, *Blakley 6534*; Isla Vista Tract, 9 Oct 1947, *C. F. Smith 2150*.

Hemizonia fasciculata (DC.) Torrey & A. Gray. Annual; common to rare; pool margins and adjacent grassland; *DS 1280, 1295(8)*.

Hemizonia increscens (Hall ex Keck) Tanowitz ssp. increscens. Tarweed. Annual; scattered along paths and on pool margins; here reaching the southern limit of its distribution.
UCSB: Del Sol Reserve, 19 Aug 1986, *Pritchett VP-11*.

Heterotheca grandiflora Nutt. Telegraph Weed. Annual or biennial; scattered; grassland and disturbed sites; *DS 1384*.

Hypochoeris glabra L. Smooth Cat's Ear. Annual; common to rare; grassland and disturbed sites; introduced; *DS 1245, 1249*.

Isocoma veneta (HBK.) E. Greene var. vernonioides (Nutt.) Jepson. [SY=Haplopappus venetus (HBK.) Blake ssp. vernonioides (Nutt.) H. M. Hall.] Coast Goldenbush. Shrub; rare (although generally common); grassland adjacent to pools; *DS 1349*.

Lactuca serriola L. Prickly Lettuce. Annual; locally common; pool margins; introduced; *DS 1316*.

Lasthenia conjugens E. Greene. Annual; rare; in pools (?). Locally extirpated? Isla Vista Tract, 9 April 1950, *C. F. Smith 2629* ; Santa Barbara, 1879, *Mrs. E. Cooper s.n.* (only known collections). Cited in R. Ornduff, "A Biosystematic Survey of the Goldfield Genus Lasthenia (Compositae: Heleniae)," in University of California Publications in Botany 40:1-92, 1966.

Lasthenia fremontii (Torrey ex A. Gray) E. Greene. Annual; rare (apparent southern limit of its distribution); in pools. Locally extirpated?
SBBG: Common on vernal flat at one end of cultivated oat field (Avena sativa) in Isla Vista Tract, 20 Apr 1950, *C. F. Smith 2649* (only collection observed from this region).

Madia sativa Mol. Chile Tarweed. Annual; locally common; pool margins and within pools; introduced; *DS 1342*.

Matricaria matricarioides (Less.) Porter. Pineapple Weed. Annual; rare; grassland and disturbed sites; introduced; *DS 1192*.

Picris echioides L. Bristly Ox Tongue. Annual; locally common to rare; grassland and disturbed sites; introduced; *DS 1350*.

Psilocarphus brevissimus Nutt. Woolly Heads. Annual; abundant to common; desiccated pools; *DS 1142*.
UCSB: Camino Corto and Abrego Road, 6 May 1967, *Keefe s.n.*
SBBG: Drying vernal pool, Isla Vista, 11 May 1973, *Edge 377c*; Vernal flat, Isla Vista Tract, 15 Jun 1950, *C. F. Smith 2807*; Vernal flat, Isla Vista Tract, 20 Apr 1950, *C. F. Smith 2670*.

Sonchus asper (L.) Hill. Prickly Sow-Thistle. Annual; scattered; pool margins; introduced; *DS 1140*.

Sonchus oleraceus L. Common Sow-Thistle. Annual; locally common to rare; pool margins; introduced; *DS 1247, 1321*.

Tragopogon porrifolius L. Salsify. Biennial; locally scattered to rare; grassland and disturbed sites; introduced; *DS 1252*.

BORAGINACEAE Borage Family

Plagiobothrys undulatus (Piper) Jtn. Popcorn Flower. Annual; common; center of pools; *DS 1050(10), 1128(14)*.
UCSB: Vernal pool, Isla Vista, 5 May 1962, *Breedlove 2660*; Del Sol site, 6 May 1967, *Keefe 1703*; Isla Vista, 11 May 1973, *Edge 377d*; Del Sol, 5 May 1978, *Katz 5*; West side of Camino Corto and El Colegio, 14 Apr 1980, *Ferren s.n.*; East of Isla Vista School, 3 May 1980, *Kiehn 81*.
SBBG: Vernal flat, Isla Vista Tract, 20 Apr 1950, *C. F. Smith 2660*; Vernal flat, Isla Vista Tract, 15 Jun 1950, *C. F. Smith 2812*; Drying edges of vernal pools, Isla Vista, 16 Jun 1952, *Pollard s.n.*; Dried vernal pool, Isla Vista, 11 May 1973, *Edge 377c*.

BRASSICACEAE Mustard Family

Brassica geniculata (Desf.) J. Ball. Biennial or perennial; common; grassland adjacent to pools; introduced. Observed but not collected.

Brassica nigra (L.) Koch. Black Mustard. Annual; locally common; margins of pools; introduced; *DS 1131(8), 1319(11)*.

Brassica rapa L. subsp. sylvestris (L.) Janchen. Field Mustard. Annual; occasional; grassland adjacent to pools; introduced. Observed but not collected.

Lepidium nitidum Nutt. Peppergrass. Annual; rare; grassland adjacent to pools and vernal flats. Not observed at Del Sol Reserve.
SBBG: Mesa west of university, Isla Vista Tract, 24 Mar 1958, *Pollard s.n.* (Pollard card file).

Raphanus raphanistrum L. Jointed Charlock. Annual; scattered to locally common; grassland adjacent to pools; introduced; *DS 1327*.

Raphanus sativus L. Wild Radish. Annual; scattered to locally common; grassland adjacent to pools; introduced; *DS 1057(10), 1328*.

CALLITRICHACEAE Water-Starwort Family

Callitriche marginata Torrey. Annual; rare; center of pools; *DS 1144(1)*.
UCSB: Camino Corto and Abrego, 6 May 1967, *Keefe 1699*.

CARYOPHYLLACEAE Pink Family

Sagina occidentalis S. Watson. Annual; rare; desiccated deeper parts of pools. Locally extirpated?
UCSB: Vernal pond, Isla Vista Tract, 13 Apr 1957, *Pollard s.n.*

Spergula arvensis L. Corn Spurry. Annual; common; margin of pools; introduced; *DS 1139(11)*.

Spergularia bocconii (Scheele) Foucaud. Sand Spurry. Annual; rare; footpaths and desiccated center of pools; introduced; *DS 1119(15), 1323*.

CHENOPODIACEAE Goosefoot Family

Atriplex semibaccata R. Br. Australian Saltbush. Perennial; uncommon to common; margins of pools and disturbed sites; introduced; *DS 1246*.

Beta vulgaris L. Garden Beet. Biennial; locally common; disturbed sites; introduced; *DS 1251*.

Chenopodium sp. Annual; rare [C. berlandieri and C. murale are expected]; disturbed sites; *DS 1324*.

CONVOLVULACEAE Morning-Glory Family

Calystegia macrostegia (E. Greene) Brummitt subsp. cyclostegia (House) Brummitt. Morning-glory. Perennial with twining stems; scattered to locally common; grassland adjacent to pools; *DS 1199, 1318*.

Convolvulus arvensis L. Bindweed. Perennial with twining stems; locally common; grassland and desiccated, open pools; introduced; *DS 1198(1)*.

Dichondra sp. Dichondra. Perennial; rare; grassland adjacent to pools; introduced?; *DS 1254*.

CRASSULACEAE Stonecrop Family

Crassula aquatica (L.) Schoenl. Annual; common; center of pools; *DS 1060(10), 1120(15), 1143(4)*.
UCSB: Vernal flat in field, Isla Vista Tract, 6 May 1956, *C. F. Smith 4467*; Camino Corto and Abrego, 20 May 1967, *Keefe 1761*; Camino Corto and Abrego, 28 Apr 1978, *Reisentz VP 44*; Camino Corto and Abrego, 20 Apr 1981, *Kuenster 173*.

Crassula erecta (Hook. & Arn.) Berger. Annual; common; openings in grassland adjacent to pools. Observed but not collected.

ELATINACEAE Waterwort Family

Elatine brachysperma A. Gray. Annual; rare; center of pools; *DS 1187*.
UCSB: Del Sol site, 8 May 1967, *Keefe 1698*; Del Sol site, 18 May 1978, *Katz 10*; Del Sol site, 14 Apr 1980, *Ferren s.n.*

EUPHORBIACEAE Spurge Family

Eremocarpus setigerus (Hook.) Benth. Dove Weed, Turkey Mullein. Annual; locally common; desiccated margins of pools and disturbed sites; *DS 1274(6)*.

FABACEAE Pea Family

Lupinus bicolor Lindley. Annual; locally scattered; grassland adjacent to pools; observed at Del Sol site, no collection.
SBBG: Roadsides and adjoining fields west of university site, Isla Vista Tract, 16 Jun 1952, 24 Mar 1958, 28 Apr 1958, 7 October 1961, 16 Mar 1962, *Pollard s.n.*

Medicago polymorpha L. Bur Clover. Annual; rare to scattered; grassland adjacent to pools; introduced; *DS 1133*.

Melilotus albus Desr. White Sweet-clover. Annual; locally scattered; grassland adjacent to pools; introduced; *DS 1322*.

Melilotus indicus (L.) All. Yellow Sweet-clover. Annual; locally scattered; disturbed areas and margins of pools; introduced; *DS 1141(11)*.

Vicia angustifolia Reichard. Common Vetch. Annual; rare to scattered; margins of pools and adjacent grassland; introduced; *DS 1055(10), 1275(6), 1277(11)*.

Vicia benghalensis L. Purple Vetch. Annual; scattered to abundant; margins of pools and adjacent grassland; introduced; *DS 1124, 1248*.

Vicia sativa L. Spring Vetch. Annual; rare to locally common; margins of pools and adjacent grassland; introduced; *DS 1136(9), 1276(11)*.

FAGACEAE Oak Family

Quercus agrifolia Nee var. agrifolia. Coast Live Oak. Tree; rare; grassland adjacent to pools; planted; *DS 1283*.

GERANIACEAE Geranium Family

Erodium botrys (Cav.) Bertol. Broad-leaf Filaree. Annual; scattered to abundant; desiccated center to margins of pools and disturbed areas; introduced; *DS 1052(10)*.

Erodium cicutarium (L.) L'Her. Annual; scattered; margins of pools and disturbed areas; introduced; no collection.

Erodium moschatum (L.) L'Her. Annual; rare; margins of pools and grasslands; introduced; *DS 1351*.

Pelargonium sp. Pelargonium. Perennial herb; rare; grassland adjacent to pools; introduced; *DS 1284*.

LAMIACEAE Mint Family

Stachys ajugoides Benth. Perennial herb; scattered; margins of pools; none observed in 1987. Observed at Del Sol by W. R. Ferren 1986.
SBBG: Flats dotted with vernal pools in Isla Vista, 16 Jun 1952, *Pollard s.n.*; Few in wet draw of open field southwest of Abrego and Camino Corto, Isla Vista, 28 Jul 1976, *C. F. Smith 11025*.

LYTHRACEAE Loosestrife Family

Lythrum hyssopifolia L. Loosestrife. Annual or perennial herb; rare to locally common; center of pools; *DS (11), (10)*.

MALVACEAE Mallow Family

Lavatera cretica L. Annual; uncommon; grassland adjacent to pools; introduced; *DS 1281, 1320, 1325*.

Malva nicaeensis All. Bull Mallow. Annual; locally common; grassland and disturbed areas adjacent to pools; introduced; *DS 1255*.

Malva parviflora L. Cheeseweed. Annual; uncommon; grassland and disturbed areas adjacent to pools; introduced; *DS 1326*.

OXALIDACEAE Wood-Sorrel Family

Oxalis corniculata L. var. corniculata. Perennial herb; locally common; disturbed sites; introduced; *DS 1292*.

PLANTAGINACEAE Plantain Family

Plantago lanceolata L. English Plantain. Annual; common; margins of pools; introduced; *DS 1053(10)*.

POLYGONACEAE Buckwheat Family

Polygonum arenastrum Bor. Common Knotweed. Annual; locally common; center to margins of desiccated pools; introduced; *DS 1253*.

Polygonum aviculare L. Annual; center to margins of desiccated pools; introduced; not observed in 1987.

Rumex angiocarpus Murbeck. Sheep Sorrel. Perennial herb; occasional to abundant; grassland and margins of pools; introduced; *DS 1061(10), 1317(4)*.

Rumex crispus L. Curly Dock. Perennial herb; scattered to common; deeper parts of pools; introduced; *DS 1345*.

PORTULACACEAE Purslane Family

Calandrinia ciliata (R. & P.) DC. var. menziesii (Hook.) Macbr. Red Maids. Annual; rare (normally a common grassland species); center of desiccated pools and open areas; *DS (3), (7)*.
SBBG: Meadow, Isla Vista Tract near university, 13 Apr 1957, *Pollard s.n.* (Pollard card file).

PRIMULACEAE Primrose Family

Anagallis arvensis L. Pimpernel. Annual; rare to common; center to margins of moist desiccated pools and disturbed areas; introduced; *DS 1134, 1197(8)*.

Centunculus minimus L. [SY=Anagallis minimus L.]. Annual; rare; vernal flats and center of moist pools; not observed in 1987.
UCSB: Del Sol site, 6 May 1967, *Keefe 1700*.

SCROPHULARIACEAE Figword Family

Veronica peregrina L. subsp. xalapensis (HBK.) Penn. Annual; rare; deeper parts of moist or desiccated pools; *DS 1196(8)*.

TROPAEOLACEAE Tropaeolum Family

Tropaeolum majus L. Garden Nasturtium. Annual; locally common; disturbed sites; introduced; *DS 1285*.

SUBCLASS MONOCOTYLEDONEAE

AMARYLLIDACEAE Amaryllis Family

Brodiaea jolonensis Eastw. Dwarf Brodiaea. Perennial herb; locally common; pool margins; not observed in 1987.
UCSB: Vernal pool northeast of junction of Camino Corto and Abrego, 12 May 1978, *Katz 9*.
SBBG: In one place on mesa of Isla Vista Tract, 20 Apr 1950, *C. F. Smith 2669*.

CYPERACEAE Sedge Family

Eleocharis acicularis (L.) R. & S. Spikerush. Perennial herb; abundant; deeper parts of pools, margins of footpaths; *DS 1130(8), 1137(10)*.
UCSB: Del Sol site, 20 May 1967, *Keefe 1753*; Del Sol site, 5 May 1978, *Katz 6*; Del Sol site, 9 May 1981, *Kuenster 180*.
SBBG: On desiccated vernal flat of Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2667*; Dried vernal pool on north side of Del Playa, 100 yards east of Devereux School boundary and Isla Vista, 13 Apr 1960, *Haller 1570*.

Eleocharis palustris (L.) R. & S. [SY=E. macrostachya Britton in Small] Spike-rush. Perennial herb; rare to abundant; deeper parts of pools; *DS 1135(9)*.
UCSB: Vernal flat in Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2668*; Del Sol site, 20 May 1967, *Keefe 1754*; Del Sol site, 21 May 1978, *Katz 19*; Del Sol site, 9 May 1981, *Kuenster 181*.
SBBG: Vernal flat in Isla Vista Tract, 20 Apr 1950, *C. F. Smith 2668*.

IRIDACEAE Iris Family

Sisyrinchium bellum S. Watson. Blue-eyed-grass. Perennial herb; rare to scattered; pool margins and adjacent grassland; *DS 1132(8)*.

JUNCACEAE Rush Family

Juncus bufonius L. var. bufonius. Toad Rush. Annual; rare to abundant; vernal flats; *DS 1186(8), 1193(11)*.
UCSB: Vernal pool in Isla Vista, 16 Apr 1960, *D.M. Smith, Flinck s.n.*; Vernal pool on Del Sol site, 20 May 1967, *Keefe 1757*; Drying vernal pool, Isla Vista, 11 May 1973, *Edge 377b*; Behind Isla Vista School, 14 May 1978, *Furukawa 22*.
SBBG: Desiccated vernal flat in Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2665*; Mesa of Isla Vista Tract, 15 Jun 1950, *C.F. Smith 2808*; Drying vernal pool, Isla Vista, 11 May 1973, *Edge 377b*.

Juncus phaeocephalus Engelm. var. phaeocephalus. Perennial herb; rare. Observed at CL and across Camino Corto from Del Sol site by W. Ferren.
SBBG: Dry beds of vernal ponds, Isla Vista Tract, 16 Jun 1952, *Pollard s.n.*.

Juncus tenuis Willd. var. congestus Engelm. Yard Rush. Perennial herb; rare to scattered; margins of pools and footpaths; *DS 1129(8), 1189(14)*.
UCSB: Del Sol site, 20 May 1967, *Keefe 1758*; Northeast junction of Camino Corto and Abrego, 16 May 1978, *Katz 17*; Del Sol site, 26 May 1980, *Roberts 108*.
SBBG: Mesa of Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2664*.

POACEAE Grass Family

Alopecurus howellii Vasey. Pacific Foxtail. Annual; rare to common; centers of pools; *DS 1127(14)*.
UCSB: Del Sol site, 16 Apr 1966, *D.M. Smith and Flinck s.n.*; Del Sol site, 20 May 1967, *Keefe 1751*; Del Sol site, 21 May 1978, *Katz 11*; Del Sol site, 31 May 1979, *Fairbank 182*; Del Sol site, 2 Jun 1979, *Corlett 53*; Del Sol site, 9 May 1981, *Kuenster 179*.
SBBG: Desiccated flats of Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2650*.

Avena barbata Brot. Slender Wild Oat. Annual; common to abundant; outer pool margins and adjacent grassland; introduced; *DS 1344(13)*.

Avena fatua L. Wild Oat. Annual; common to abundant; grassland and drying pools; introduced; *DS 1314*.

Bromus diandrus Roth. Ripgut Grass. Annual; rare to abundant; pool margins and adjacent grassland; introduced; *DS 1056(10)*.

Bromus hordeaceus L. [SY = Bromus mollis L.]. Soft Chess. Annual; scattered to common; pool margins and adjacent grassland; introduced; *DS 1058(10)*.

Cynodon dactylon (L.) Pers. Bermuda Grass. Perennial; uncommon to abundant; pool margins and adjacent grassland; introduced; *DS 1256(14)*.

Deschampsia danthonioides (Trin.) Munro ex Benth. Annual; rare; vernal flats. Locally extirpated?
SBBG: In grassy former vernal pool area of Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2653*.

Distichlis spicata (L.) E. Greene var. spicata. Salt Grass. Perennial; common; pool margins and grassland; *DS 1250*.

Festuca arundinacea Schreb. Perennial; introduced; observed by W. Ferren at Del Sol in 1987, none collected.

Gastridium ventricosum (Gouan) Schinz & Thell. Nitgrass. Annual; introduced; observed at Del Sol by W. Ferren; no collections from vernal pool sites.

Hordeum brachyantherum Nevski. Meadow Barley. Perennial; rare to abundant; deeper parts of pools; *DS 1051(10), 1123(14)*.
UCSB: Del Sol site, *Keefe 1726*; Del Sol site, 20 May 1967, *Keefe 1755, 1756*; Del Sol site, 20 Apr 1981, *Kuenster 175*.
SBBG: Meadow on El Colegio Road, Isla Vista, 3 May 1967, *Pollard s.n.*

Hordeum californicum Covas & Stebbins. California Barley. Perennial; rare to common; outer pool margins and footpath margins.
UCSB: Del Sol site, 31 May 1979, *Fairbanks 184*; Del Sol site, 31 May 1983, *Strong 108*.

Hordeum geniculatum Allioni. Mediterranean Barley. Annual; rare to common; center to margins of moist or desiccated pools; introduced; *DS 1190(14), 1195(8)*.

Hordeum murinum L. [including H. leporinum Link and H. glaucum Steud.] Annual; common; grassland or disturbed areas; introduced; *DS 1121*.

Lolium multiflorum Lam. [SY= L. perenne subsp. multiflorum (Lam.) Husnot]. Italian Ryegrass. Annual; abundant; pools, pool margins, and grassland; introduced; *DS 1121*.

Oryzopsis miliacea (L.) Benth. Rice Grass. Perennial; rare near pools but an otherwise common species; grassland; introduced; *DS 1282*.

Phalaris lemmonii Vasey. Annual; rare to common; center of pools; *DS 1126(14); 1191(14)*.
UCSB: Del Sol site, 16 Apr 1966, *Flinck & D.M. Smith s.n.*; Del Sol site, 31 May 1979, *Fairbank 183*; Del Sol site, 2 Jun 1979, *Corlett 52*; Del Sol site, 9 May 1981, *Kuenster 178*.
SBBG: Desiccated vernal flat of Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2654*.

Poa annua L. Annual Bluegrass. Annual; common; along footpaths and in disturbed sites in pools; introduced; *DS 1348(10)*.

Polypogon interruptus HBK. Annual; common; center to margins of pools; introduced; *DS 1200(14)*.

Vulpia bromoides (L.) S.F. Gray. Annual; occasional to abundant; grassland and pool margins; introduced; *DS 1059(10), 1194(5)*.

APPENDIX III

A CATALOGUE OF THE VASCULAR PLANTS OF THE VERNAL POOLS AND RELATED UPLAND HABITATS OF ISLA VISTA, ELLWOOD MESA, AND MORE MESA, SANTA BARBARA COUNTY, CALIFORNIA

Compiled by

Holly C. Forbes[1]

UCSB Herbarium
Department of Biological Sciences
University of California, Santa Barbara

[1] Current Address: University Botanical Garden,
University of California, Berkeley, CA 94720

INTRODUCTION

The vernal pools on the Del Sol site, the property southeast of the intersection of El Colegio Road and Camino Corto in Isla Vista, are the subject of a restoration project being conducted through the Herbarium of the University of California at Santa Barbara (UCSB). To aid in this restoration, a collection of voucher specimens was made in 1987 from the Del Sol pools and other pools on the south coast of Santa Barbara County. In addition, a search of native vernal pool species preserved in the Herbaria of UCSB and the Santa Barbara Botanic Garden (SBBG) was made to ascertain as much as possible the historical presence/occurrence of vernal pool species in this area. Information obtained through these two avenues is here compiled in an annotated catalogue.

This catalogue includes all native and naturalized vascular plants that were collected or observed during this study, collected or observed by others during concurrent or previous studies, or reported in the literature from these areas. The catalogue is arranged according to a phylogenetic arrangement of ferns, gymnosperms, and angiosperms, and within the latter by dicotyledons and monocotyledons. The families, genera, and species are listed in alphabetical order within each group.

The information given for each plant may include the following: scientific name, common name (if one exists), habit (annual, perennial herb, shrub, tree), local abundance (relative number of plants at any one site), approximate position in the vernal pools, "introduced" if it is not native to the area, and collection number(s) of H. C. Forbes from 1987 (specimens deposited at UCSB Herbarium). The abbreviations used for the Forbes collections are defined as follows: DS is the Del Sol site, numbers in () indicate the pool on the site from which the collection was made; CL is the Camino Lindo pool near Del Playa; EWE is the easternmost pool on Ellwood Mesa; EWW is west of the previous pool on the Ellwood Mesa; FT is the pool north of Francisco Torres dormitory, toward the center of the field; MM is the pool on More Mesa; and WC is the complex of created pools on West Campus, UCSB. This list is followed by a list of specimens at the UCSB and SBBG Herbaria and any listed in the Henry M. Pollard card file (located at SBBG).

Although most of the nomenclature is consistent with Munz (1959, 1968, 1974), other names have been applied to some plants more recently, in which case synonyms may also be listed.

DIVISION TRACHEOPHYTA

SUBDIVISION PTEROPSIDA

CLASS FILICAE

MARSILEACEAE Marsilea Family

Pilularia americana A. Braun. Pillwort. Perennial fern; locally common in wet years.
UCSB: Del Sol site, northeast corner of lot, 20 Apr 1981, *G. Kuenster 177*; Del Sol site, 21 May 1978, *S. J. Katz 7*; Del Sol site, northeast of Camino Corto and Abrego Road, 24 Apr 1974, *R. Broder, s.n.*

CLASS CONIFERAE

PINACEAE Pine Family

Pinus sp. Pine. Tree; rare; not in pools; planted; *DS 1279*.

CLASS ANGIOSPERMAE

SUBCLASS DICOTYLEDONEAE

AIZOACEAE Carpet Weed Family

Carpobrotus edulis (L.) Bolus. Hottentot-Fig. Prostrate succulent shrub; rare; margin of pools; introduced; *DS 1293(11)*.

APIACEAE Celery Family

Eryngium armatum (S. Watson) Coulter & Rose. Coyote Thistle. Perennial herb; locally common; pool margins; *CL 1171a*.
UCSB: South of Camino Lindo and Del Playa, 9 May 1981, *Kuenster 185* ; Del Playa at Camino Lindo, 20 Apr 1981, *Ferren 2417*; Camino Lindo and Del Playa, 24 Mar 1980, *Reisentz s.n.*; Vacant lot behind 6788 Abrego, 4 Jun 1979, *Schiell s.n.*; Northeast of junction of Camino Corto and Abrego, 26 May 1978, *Katz 66*; Vernal flats in fields of Isla Vista, 6 May 1956, *C. F. Smith 4461*.
SBBG: Vernal flats in fields of Isla Vista Tract above ocean, 6 May 1956, *C. F. Smith 4461*; Vernal flats in Isla Vista, 20 Apr 1950, *C. F. Smith 2659*; Mesa of Isla Vista Tract, 15 Jun 1950, *C. F. Smith 2803*.

Eryngium vaseyi Coulter & Rose. Coyote Thistle. Perennial herb; common; center of pools; *DS 1125; CL 1171, 1175; FT 1238; EWE 1082, 1290; EWW 1064, 1289; MM 1150; WC 1103, 1109*.
UCSB: More Mesa, 21 Apr 1982, *Steele 82-138*; More Mesa, 22 Jul 1981, *Steele 82-2*; Ellwood Mesa 0.2 km west of Isla Vista, 1 km south of Ellwood Station,

23 Jun 1981, *Thomson 98*; Ellwood Mesa, Pool J, 21 May 1981, *Thomson 62*; Camino Corto and Abrego, 9 May 1981, *Kuenster 184*; Ellwood Mesa 0.2 km west of Isla Vista, 1 km south of Ellwood Station, 3 May 1981, *Thomson 76*, ; Ellwood Mesa 0.2 km west of Isla Vista, 1 km south of Ellwood Station, 25 Apr 1981, *Thomson 13*; Camino Lindo and Del Playa, 24 Mar 1980, *Reisentz s.n.*; Camino Corto and Abrego, 20 May 1967, *Keefe 1752*; Vernal pool in Isla Vista, 31 May 1962, *Breedlove 2886*; Vernal flats in fields of Isla Vista Tract, 6 May 1956, *C. F. Smith 4460*.
SBBG: Vernal flats of Isla Vista Tract, 15 June 1950, *C. F. Smith 2804*; Vernal flats of Isla Vista Tract, 20 Apr 1950, *C. F. Smith 2658*; Vernal flats of Isla Vista Tract, 9 Oct 1947, *C. F. Smith 2152*.

Foeniculum vulgare Mill. Sweet Fennel. Perennial herb; common; grassland adjacent to pools; introduced; *DS 1271; CL 1266; WC 1304*.

ASCLEPIADACEAE Milkweed Family

Asclepias fascicularis Dcne. in A. DC. Narrowleaf Milkweed. Perennial herb; locally common; grassland adjacent to pools; *DS 1272*.

ASTERACEAE Sunflower Family

Ambrosia psilostachya DC. var. californica (Rydb.) Blake. Western Ragweed. Perennial herb; common; grassland and margins of pools; *DS 1343; CL 1341; WC 1118, 1336*.

Baccharis glutinosa Pers. Mule Fat. Shrub; rare near pools but common elsewhere; elevated mounds in vernal pool. *WC 1335*.

Baccharis pilularis DC. subsp. consanguinea (DC.) C. B. Wolf. Coyote Bush. Shrub; locally common; grassland; *DS 1273; MM 1263; WC 1305*.

Carduus pycnocephalus L. Italian Thistle. Annual; rare; disturbed sites and grassland; introduced; *DS 1315*.

Conyza canadensis (L.) Cronq. Horseweed. Annual; locally scattered; pool margins and adjacent grassland; *DS 1347*.

Cotula coronopifolia L. Brass Buttons. Perennial herb; uncommon to common; center of pools; introduced; *DS 1138(10); CL 1176; EWE 1081a; EWW 1070; WC 1099*.

Gnaphalium californicum DC. Green Everlasting. Biennial; not in pools; rare near pools but common elsewhere; *DS 1278*.

Gnaphalium luteoalbum L. Annual; rare; margin of pools; introduced; *WC 1093, 1298*.

Gnaphalium palustre Nutt. Woolly Everlasting. Annual; locally common; pool margins; *WC 1297*.
UCSB: Ellwood Mesa, Pool A, 31 May 1981, *Thomson 87*; Vernal flat, horse pasture and east of Devereux School on West Campus, 13 Aug 1980, *Steele, Whitmore, Koehler, Ferren s.n.*; Del Playa and Camino Corto, 8 May 1967, *Keefe 1724*; Camino Corto and Abrego Road, 6 May 1967, *Keefe 1702*.

Grindelia robusta Nutt. Gumplant. Perennial herb; locally common; margins of pools and along footpaths; *DS 1296*.
UCSB: Del Playa and Camino Majorca, 10 May 1982, *DeGrange 23*; West end of Del Playa, 5 Jun 1977, *Connor 63*; Del Playa and Camino Majorca, 30 May 1973, *Bagley 66*.

Hemizonia australis (Keck) Keck. Spikeweed. Annual; locally common to rare [CNPS List 3], here reaching the northern limit of its distribution; center to margins of desiccated pools; *DS 1294(11); CL 1171, 1306; EWE 1333; EWW 1330; WC 1340*.
UCSB: Ellwood Mesa in field, 23 Jun 1981, *Thomson 99*; Near Coal Oil Point lagoon (West Campus), 18 April 1977, *Noel 64*.
SBBG: Dried vernal flat southeast of Del Playa and Camino Lindo, 14 Feb 1977, *Philbrick s.n.*; East of Isla Vista School, 15 Sep 1964, *Blakley 6534*; Isla Vista Tract, 9 Oct 1947, *C. F. Smith 2150*.

Hemizonia fasciculata (DC.) Torrey & A. Gray. Annual; common to rare; pool margins and adjacent grassland; *DS 1280, 1295(8); EWW 1329; MM 1260; WC 1117, 1299*.
UCSB: More Mesa vernal pool area, 2 Sep 1981, *Steele 81-36*; Ellwood Mesa field, 6 Jun 1981, *Thomson 94*; East side of Devereux School, 27 May 1980, *Kiehn 90*; Coal Oil Point Reserve, west of slough, 2 Nov 1979, *Baldwin s.n.*; Devereux Point, 12 Apr 1977, *Bullwinkle 50*; West Campus, northwest side of channel along dirt road, 13 Aug 1970, *Boyce 96*; Del Playa and Camino Corto, 20 May 1967, *Keefe 1740*.

Hemizonia increscens (Hall ex Keck) Tanowitz ssp. increscens. Tarweed. Annual; scattered along paths and on pool margins; here reaching the southern limit of its distribution.
UCSB: Del Sol Reserve, 19 Aug 1986, Pritchett VP-11.

Heterotheca grandiflora Nutt. Telegraph Weed. Annual or biennial; scattered; grassland and disturbed sites; *DS 1384*.

Hypochoeris glabra L. Smooth Cat's Ear. Annual; common to rare; grassland and disturbed sites; introduced; *DS 1245, 1249; EWW 1078; MM 1165; WC 1102*.

Isocoma veneta (HBK.) E. Greene var. vernonioides (Nutt.) Jepson. [SY=Haplopappus venetus (HBK.) Blake ssp. vernonioides (Nutt.) H. M. Hall]. Coast Goldenbush. Shrub; common to rare; grassland adjacent to pools; *DS 1349; CL 1307; EWW 1332*.

Lactuca serriola L. Prickly Lettuce. Annual; locally common; pool margins; introduced; *DS 1316; FT 1354*.

Lasthenia conjugens E. Greene. Annual; rare; in pools (?). Locally extirpated? Isla Vista Tract, 9 April 1950, *C. F. Smith 2629* ; Santa Barbara, 1879, *Mrs. E. Cooper s.n.* (only known collections). Cited in R. Ornduff, "A Biosystematic Survey of the Goldfield Genus Lasthenia (Compositae: Heleniae)," in University of California Publications in Botany 40:1-92, 1966.

Lasthenia fremontii (Torrey ex A. Gray) E. Greene. Annual; rare (apparent southern limit of its distribution); in pools. Locally extirpated?

SBBG: Common on vernal flat at one end of cultivated oat field (Avena sativa) in Isla Vista Tract, 20 Apr 1950, *C. F. Smith 2649* (only collection observed from this region).

Madia sativa Mol. Chile Tarweed. Annual; locally common; pool margins and within pools; introduced; *DS 1342*.

Matricaria matricarioides (Less.) Porter. Pineapple Weed. Annual; rare; grassland and disturbed sites; introduced; *DS 1192*.

Picris echioides L. Bristly Ox Tongue. Annual; locally common to rare; grassland and disturbed sites; introduced; *DS 1350; CL 1312; FT 1353; WC 1303*.

Psilocarphus brevissimus Nutt. Woolly Heads. Annual; abundant to common; desiccated pools; *DS 1142; EWE 1089; EWW 1065, 1226; WC 1112*.
UCSB: Ellwood Mesa Pool A, 15 May 1981, *Thomson 46*; Ellwood Mesa Pool A, 25 Apr 1981, *Thomson 16*; East side of Devereux School, 27 May 1980, *Kiehn 89*; East side of Devereux School, 2 May 1980, *Ferren 2181 and Whitmore s.n.*; Del Playa and Camino Corto, 8 May 1967, *Keefe 1735*; Ellwood Mesa, south of Mathilda Dr., 7 May 1967, *Keefe 1709*; Camino Corto and Abrego Road, 6 May 1967, *Keefe s.n.*
SBBG: Drying vernal pool, Isla Vista, 11 May 1973, *Edge 377c*; Vernal flat, Isla Vista Tract, 15 Jun 1950, *C. F. Smith 2807*; Vernal flat, Isla Vista Tract, 20 Apr 1950, *C. F. Smith 2670*.

Psilocarphus tenellus Nutt. Annual; rare; adjacent grassland and scrubland and desiccated centers of pools.
UCSB: Ellwood Mesa Pool A, 5 May 1981, *Thomson 46*.

Sonchus asper (L.) Hill. Prickly Sow-Thistle. Annual; scattered; pool margins; introduced; *DS 1140; WC 1098a*.

Sonchus oleraceus L. Common Sow-Thistle. Annual; locally common to rare; pool margins; introduced; *DS 1247, 1321; WC 1334*.

Tragopogon porrifolius L. Salsify. Biennial; locally scattered to rare; grassland and disturbed sites; introduced; *DS 1252; CL 1270; WC 1235*.

BORAGINACEAE Borage Family

Plagiobothrys undulatus (Piper) Jtn. Popcorn Flower. Annual; common; center of pools; *DS 1050(10), 1128(14); CL 1168; EWE 1080; EWW 1062; MM 1145; WC 1111*.
UCSB: Vacant lot between Trigo and Sabado Tarde, west of Camino del Sur, 15 Apr 1960, *Haller 1572*; Vernal pool, Isla Vista, 5 May 1962, *Breedlove 2660*; Del Sol site, 6 May 1967, *Keefe 1703*; Del Playa and Camino Corto, 8 May 1967, *Keefe 1734*; Isla Vista, 11 May 1973, *Edge 377d*; 775 Camino del Sur, Isla Vista, 4 Feb 1977, *Keller 6*; Del Sol, 5 May 1978, *Katz 5*; West side of Camino Corto and El Colegio, 14 Apr 1980, *Ferren s.n.*; East side of Devereux School, 2 May 1980, *Ferren and Whitmore 2174*; East of Isla Vista School, 3 May 1980, *Kiehn 81*; Ellwood Mesa Pool A, 11 Apr 1981, *Thomson 5b*; Ellwood Mesa Pool A, 11 Apr 1981, *Thomson 5a*; More Mesa, 21 Apr 1982, *Steele 82-126*.
SBBG: Vernal flat, Isla Vista Tract, 20 Apr 1950, *C. F. Smith 2660*; Vernal flat, Isla Vista Tract, 15 Jun 1950, *C. F. Smith 2812*; Drying edges of vernal

pools, Isla Vista, 16 Jun 1952, *Pollard s.n.*; Sandy, grassy bluff around vernal pool in Isla Vista, 5 May 1962, *Breedlove 2660*; Vernal pool on Del Playa Drive, 3 May 1967, *Pollard s.n.* (2 sheets); Dried vernal pool, Isla Vista, 11 May 1973, *Edge 377c*; Dried vernal pool southeast of Del Playa and Camino Lindo, 14 Feb 1977, *Philbrick s.n.*

BRASSICACEAE Mustard Family

Brassica geniculata (Desf.) J. Ball. Biennial or perennial; common; grassland adjacent to pools; introduced.

Brassica nigra (L.) Koch. Black Mustard. Annual; locally common; margins of pools; introduced; *DS 1131(8), 1319(11)*.

Brassica rapa L. subsp. sylvestris (L.) Janchen. Field Mustard. Annual; occasional; grassland adjacent to pools; introduced.

Lepidium nitidum Nutt. Peppergrass. Annual; rare; grassland adjacent to pools and vernal flats.
UCSB: Ellwood Mesa in pathway, 19 Apr 1981, *Thomson 19*.
SBBG: Mesa west of university, Isla Vista Tract, 24 Mar 1958, *Pollard s.n.* (Pollard card file).

Raphanus raphanistrum L. Jointed Charlock. Annual; scattered to locally common; grassland adjacent to pools; introduced; *DS 1327; CL 1204, 1309; WC 1114, 1337*.

Raphanus sativus L. Wild Radish. Annual; scattered to locally common; grassland adjacent to pools; introduced; *DS 1057(10), 1328; CL 1308; FT 1356; WC 1338*.

CALLITRICHACEAE Water-Starwort Family

Callitriche marginata Torrey. Annual; rare; center of pools; *DS 1144(1); EWE 1079; EWW 1067*.
UCSB: Camino Corto and Abrego, 6 May 1967, *Keefe 1699*; Del Playa and Camino Corto, 8 May 1967, *Keefe 1720*; Ellwood Mesa Pool A, 25 Apr 1981, *Thomson 12*.

CARYOPHYLLACEAE Pink Family

Sagina occidentalis S. Watson. Annual; rare; desiccated deeper parts of pools.
UCSB: Vernal pond, Isla Vista Tract, 13 Apr 1957, *Pollard s.n.*

Spergula arvensis L. Corn Spurry. Annual; common; margin of pools; introduced; *DS 1139(11); WC 1113*.

Spergularia bocconii (Scheele) Foucaud. Sand Spurry. Annual; rare; desiccated center of pools and footpaths; introduced; *DS 1119(15), 1323; EWE 1216*.

Spergularia villosa (Pers.) Camb. Perennial; uncommon to common; footpaths, disturbed areas and desiccated pools; introduced; *EWW 1225; MM 1161*.

CHENOPODIACEAE Goosefoot Family

Atriplex semibaccata R. Br. Australian Saltbush. Perennial; uncommon to common; margins of pools and disturbed sites; introduced; *DS 1246; EWW 1331.*

Beta vulgaris L. Garden Beet. Biennial; locally common; disturbed sites; introduced; *DS 1251.*

Chenopodium sp. Annual; rare [C. berlandieri and C. murale are expected]; disturbed sites; *DS 1324.*

CONVOLVULACEAE Morning-Glory Family

Calystegia macrostegia (E. Greene) Brummitt subsp. cyclostegia (House) Brummitt. Morning-glory. Perennial with twining stems; scattered to locally common; grassland adjacent to pools; *DS 1199, 1318; CL 1268; WC 1301.*

Convolvulus arvensis L. Bindweed. Perennial with twining stems; locally common; grassland and desiccated open pools; introduced; *DS 1198(1); CL 1265.*

Dichondra sp. Dichondra. Perennial; rare; grassland adjacent to pools; introduced; *DS 1254.*

CRASSULACEAE Stonecrop Family

Crassula aquatica (L.) Schoenl. Annual; common; center of pools; *DS 1060(10), 1120(15), 1143(4); EWE 1082a, EWW 1066.*
UCSB: Vernal flat in field, Isla Vista Tract, 6 May 1956, *C. F. Smith 4467*; Del Playa and Camino Corto, 8 May 1967, *Keefe 1736*; Camino Corto and Abrego, 20 May 1967, *Keefe 1761*; Camino Corto and Abrego, 28 Apr 1978, *Reisentz VP 44*; Vernal flat east of Devereux School, 13 Aug 1980, *Steele, Whitmore, Koehler, Ferren s.n.*; Camino Corto and Abrego, 20 Apr 1981, *Kuenster 173*; Ellwood Mesa Pool B with C, 1 May 1981, *Thomson 107.*
SBBG: Drying mud flat along road in Isla Vista Tract above ocean, 16 Apr 1951, *C. F. Smith 3011.*

Crassula erecta (Hook. & Arn.) Berger. Annual; common; openings in grassland adjacent to pools.
UCSB: Ellwood Mesa Pool B with C, 1 May 1981, *Thomson 108.*

ELATINACEAE Waterwort Family

Elatine brachysperma A. Gray. Annual; rare; center of pools; *DS 1187.*
UCSB: Ellwood Mesa, south of Mathilda Drive, 7 May 1967, *Keefe 1708*; Del Sol site, 8 May 1967, *Keefe 1698*; Del Sol site, 18 May 1978, *Katz 10*; Del Sol site, 14 Apr 1980, *Ferren s.n.*

EUPHORBIACEAE Spurge Family

Eremocarpus setigerus (Hook.) Benth. Dove Weed, Turkey Mullein. Annual; locally common; desiccated margins of pools and disturbed sites; *DS 1274(6).*
UCSB: 6867 Sabado Tarde, 15 Jun 1960, *Haller 1706*; Vernal flat (dry) east of Devereux School, 13 Aug 1980, *Steele, Whitmore, Koehler, Ferren s.n.*; Ellwood Mesa field, 2 May 1981, *Thomson 102.*

FABACEAE Pea Family

Lupinus bicolor Lindley. Annual; locally scattered; grassland adjacent to pools; observed at Del Sol site, no collection.
SBBG: Roadsides and adjoining fields west of university site, Isla Vista Tract, 16 Jun 1952, 24 Mar 1958, 28 Apr 1958, 7 October 1961, 16 Mar 1962, *Pollard s.n.*

Medicago polymorpha L. Bur Clover. Annual; rare to scattered; grassland adjacent to pools; introduced; *DS 1133; CL 1180; EWE 1087; MM 1156; WC 1105.*

Melilotus albus Desr. White Sweet-clover. Annual; locally scattered; grassland adjacent to pools; introduced; *DS 1322.*

Melilotus indicus (L.) All. Yellow Sweet-clover. Annual; locally scattered; disturbed areas and margins of pools; introduced; *DS 1141(11).*

Trifolium hirtum All. Rose Clover. Annual; rare; grassland adjacent to pools; introduced; *MM 1163.*

Vicia angustifolia Reichard. Common Vetch. Annual; rare to scattered; margins of pools and adjacent grassland; introduced; *DS 1055(10), 1275(6), 1277(11).*

Vicia benghalensis L. Purple Vetch. Annual; scattered to abundant; margins of pools and adjacent grassland; introduced; *DS 1124, 1248; CL 1174; WC 1227.*

Vicia dasycarpa Ten. Smooth Vetch. Annual; rare; margins of pools; *WC 1104.*

Vicia sativa L. Spring Vetch. Annual; rare to locally common; margins of pools and adjacent grassland; introduced; *DS 1136(9), 1276(11); CL 1181; FT 1244a; EWE 1291; WC 1234.*

FAGACEAE Oak Family

Quercus agrifolia Nee var. agrifolia. Coast Live Oak. Tree; rare; grassland adjacent to pools; planted; *DS 1283.*

GENTIANACEAE Gentian Family

Centaurium floribundum (Benth.) Rob. Annual; rare; center of pools and moist open soil.
UCSB: Ellwood Mesa in field, 6 Jun 1981, *Thomson 95.*
SBBG: Along railroad at Ellwood, 28 Jun 1948, *Cravens s.n.*; Along Pacific Oaks Road in Ellwood area west of Goleta, 30 Jun 1983, *Blakley 7297.*

GERANIACEAE Geranium Family

Erodium botrys (Cav.) Bertol. Broad-leaf Filaree. Annual; scattered to abundant; moist or desiccated center to margins of pools and disturbed areas; introduced; *DS 1052(10); EWW 1076.*

Erodium cicutarium (L.) L'Her. Annual; scattered; margins of pools and disturbed areas; introduced; *EWW 1077*.

Erodium moschatum (L.) L'Her. Annual; rare; margins of pools, grassland, and disturbed areas; introduced; *DS 1351*.

Geranium dissectum L. Cutleaf Geranium. Annual; rare to scattered; margins of pools; introduced; *EWE 1090; WC 1108*.

Pelargonium sp. Pelargonium. Perennial herb; rare; grassland adjacent to pools; introduced; *DS 1284*.

LAMIACEAE Mint Family

Stachys ajugoides Benth. Perennial herb; scattered; margins of pools; *WC 1107, 1229*. Observed at Del Sol by W. R. Ferren in 1987.
UCSB: Ellwood Mesa in field, 7 May 1981, *Thomson 53*.
SBBG: Flats dotted with vernal pools in Isla Vista, 16 Jun 1952, *Pollard s.n.*; Few in wet draw of open field southwest of Abrego and Camino Corto, Isla Vista, 28 Jul 1976, *C. F. Smith 11025*.

LYTHRACEAE Loosestrife Family

Lythrum hyssopifolia L. Loosestrife. Annual or perennial herb; rare to locally common; center of pools; *DS (11), (10); EWE 1088, 1213; EWW 1075; MM 1160; WC 1230*.
UCSB: Camino Corto and Del Playa (100 yards southwest), 20 May 1967, *Keefe 1739*; 6867 Sabado Tarde, 23 Jul 1967, *Haller 2196*; West Campus vernal pool, north of northern boundary of Coal Oil Point Reserve, 22 Mar 1980, *Whitmore s.n.*; West Campus, east of Devereux School, 2 May 1980, *Whitmore and Ferren 2180a*; Ellwood Mesa Pool B, 17 May 1981, *Thomson 58*.

MALVACEAE Mallow Family

Lavatera cretica L. Annual; uncommon; grassland adjacent to pools; introduced; *DS 1281, 1320, 1325*.

Malva nicaeensis All. Bull Mallow. Annual; locally common; grassland and disturbed areas adjacent to pools; introduced; *DS 1255*.

Malva parviflora L. Cheeseweed. Annual; uncommon; grassland and disturbed areas adjacent to pools; introduced; *DS 1326; CL 1313*.

Malvella leprosa (Ortega) Krapov. Alkali Mallow; Perennial herb; common; center to margins of desiccated pools; *FT 1243; MM 1208, 1262*.
UCSB: West Campus, east of Devereux School, 2 May 1980, *Whitmore and Ferren 2178* .

ONAGRACEAE Evening Primrose Family

Boisduvalia glabella (Nutt.) Walp. Annual; locally common; moist or desiccated center of pools; *EWW 1226a, 1287*.
UCSB: West Campus, east of Devereux School, 2 May 1980 and 13 Aug 1980, *Steele, Whitmore, Koehler, Ferren s.n.*; Ellwood Mesa in vernal pool, 7 May

1981, *Thomson 56*; Ellwood Mesa Pool O, 17 May 1981, *Thomson 59*; Ellwood Mesa Pool O, 6 Jun 1981, *Thomson 96*.

OXALIDACEAE Wood-Sorrel Family

Oxalis corniculata L. var. corniculata. Perennial herb; locally common; disturbed sites; introduced; *DS 1292*.

PLANTAGINACEAE Plantain Family

Plantago bigelovii A. Gray subsp. bigelovii. Annual; rare but locally abundant; grazed vernal flats; not observed in 1987. Locally extirpated?
UCSB: Vernal flat east of Devereux School, West Campus, 13 Aug 1980, *Steele, Whitmore, Koehler, Ferren s.n.* (last collection before site destroyed).
SBBG: Ocean bluffs west of Devereux School, Goleta, 25 Mar 1960 and 26 Nov 1962, *Pollard s.n.*

Plantago lanceolata L. English Plantain. Annual; common; margins of pools; introduced; *DS 1053(10); CL 1185; EWE 1219; EWW 1069; MM 1159; WC 1098*.

POLYGONACEAE Buckwheat Family

Polygonum arenastrum Bor. Common Knotweed. Annual; locally common; center to margins of moist or desiccated pools; introduced; *DS 1253; EWW 1071, 1288; WC 1302*.

Polygonum aviculare L. Annual; center to margins of desiccated pools; introduced; not observed in 1987.

Rumex angiocarpus Murbeck. Sheep Sorrel. Perennial herb; occasional to abundant; grassland and margins of pools; introduced; *DS 1061(10), 1317(4); MM 1154; WC 1106*.

Rumex crispus L. Curly Dock. Perennial herb; scattered to common; deeper parts of pools; introduced; *DS 1345; CL 1264; FT 1240; EWE 1085; EWW 1068; MM 1205; WC 1228*.

PORTULACACEAE Purslane Family

Calandrinia ciliata (R. & P.) DC. var. menziesii (Hook.) Macbr. Red Maids. Annual; rare (normally a common grassland species); center of desiccated pools and open areas; *DS (3), (7)*.
SBBG: Meadow, Isla Vista Tract near University, 13 Apr 1957, *Pollard s.n.* (Pollard card file).

PRIMULACEAE Primrose Family

Anagallis arvensis L. Pimpernel. Annual; rare to common; center to margins of moist or desiccated pools and disturbed areas; introduced; *DS 1134, 1197(8); MM 1152; WC 1095*.

Centunculus minimus L. [SY=Anagallis minimus L.]. Annual; rare; vernal flats and center of moist pools; not observed in 1987.
UCSB: Del Sol site, 6 May 1967, *Keefe 1700*; 100 yards southwest of Del Playa and Camino Corto, 8 May 1967, *Keefe 1720*; Ellwood Mesa, locally common in outer zone of vernal pools, *Thomson 78* (cited in report, specimen not found).

SCROPHULARIACEAE Figword Family

Orthocarpus densiflorus Benth. var. densiflorus. Owl's Clover. Annual; rare; outer margin of pools and open grasslands; *EWW 1073*.

Veronica peregrina L. subsp. xalapensis (HBK.) Penn. Annual; rare; deeper parts of moist or desiccated pools; *DS 1196(8)*.
UCSB: 100 yards southwest of Del Playa and Camino Corto, 8 May 1967, *Keefe 1737*; West Campus, east of Devereux School, 2 May 1980, *Whitmore and Ferren 2177*; Ellwood Mesa, 7 May 1981, *Thomson 55*.

TROPAEOLACEAE Tropaeolum Family

Tropaeolum majus L. Garden Nasturtium. Annual; locally common; disturbed sites; introduced; *DS 1285*.

SUBCLASS MONOCOTYLEDONEAE

AMARYLLIDACEAE Amaryllis Family

Brodiaea jolonensis Eastw. Dwarf Brodiaea. Perennial herb; locally common; pool margins; *CL 1201*.
UCSB: On sandy, grassy bluff around vernal pool in Isla Vista, 5 May 1962, *Breedlove 2658*; South side of Del Playa 75 feet west of Camino Corto, 6 May 1967, *Keefe 1704*; Vernal pool northeast of junction of Camino Corto and Abrego, 12 May 1978, *Katz 9*; South side of Del Playa at Camino Lindo, 20 Apr 1981, *Ferren 2416*; More Mesa in northwest section, 4 May 1982, *Steele and Hannan 82-221*.
SBBG: In one place on mesa of Isla Vista Tract, 20 Apr 1950, *C. F. Smith 2669*; Near dried vernal pool, west end of Del Playa, Isla Vista, 14 May 1973, *Edge 379*.

CYPERACEAE Sedge Family

Cyperus eragrostis Lam. Perennial herb; scattered; deeper parts of pools; *FT 1355; EWE 1086*.

Eleocharis acicularis (L.) R. & S. Spikerush. Perennial herb; abundant; deeper parts of pools, margins of footpaths; *DS 1130(8), 1137(10); CL 1173; EWE 1081; EWW 1063; MM 1151; WC 1110*.
UCSB: Vernal pool 100 yards east of Devereux School, 13 Apr 1960, *Haller 1570*; On sandy, grassy bluff around vernal pool, Isla Vista, 5 May 1962, *Breedlove 2661*; 100 yards southwest of Del Playa and Camino Corto, 8 May 1967, *Keefe 1725*; Del Sol site, 20 May 1967, *Keefe 1753*; Del Sol site, 5 May 1978, *Katz 6*; West Campus vernal pool north of parking lot, 15 Mar 1980, *Whitmore 80-01043*; Ellwood Mesa Pool A, 11 Apr 1981, *Thomson 4*; Ellwood Mesa Pool A, 5

May 1981, *Thomson 50*; Del Sol site, 9 May 1981, *Kuenster 180*; More Mesa vernal pool, 21 Apr 1982, *Steele 82-130*.
SBBG: On desiccated vernal flat of Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2667*; Dried vernal pool on north side of Del Playa, 100 yards east of Devereux School boundary and Isla Vista, 13 Apr 1960, *Haller 1570*.

Eleocharis palustris (L.) R. & S. [SY=E. macrostachya Britton in Small] Spike-rush. Perennial herb; rare to abundant; deeper parts of pools; *DS 1135(9); FT 1244; EWE 1083; EWW 1070a; MM 1147; WC 1116*.
UCSB: Vernal flat in Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2668*; Sandy, grassy bluff around vernal pool, Isla Vista, 5 May 1962, *Breedlove 2662*; Del Sol site, 20 May 1967, *Keefe 1754*; Del Sol site, 21 May 1978, *Katz 19*; West Campus vernal pool, 30 meters north of boundary of Coal Oil Point Reserve, 22 Mar 1980, *Whitmore s.n.*; Del Sol site, 9 May 1981, *Kuenster 181*; West Campus vernal pool north of parking lot, 15 Mar 1980, *Whitmore 80-01042*; Ellwood Mesa Pool A, 11 Apr 1981, *Thomson 1*; More Mesa vernal pool, 21 Apr 1982, *Steele 82-128*.
SBBG: Vernal flat in Isla Vista Tract, 20 Apr 1950, *C. F. Smith 2668*.

IRIDACEAE Iris Family

Sisyrinchium bellum S. Watson. Blue-eyed-grass. Perennial herb; rare to scattered; pool margins and adjacent grassland; *DS 1132(8); CL 1184; MM 1162*.

JUNCACEAE Rush Family

Juncus bufonius L. var. bufonius. Toad Rush. Annual; rare to abundant; vernal flats; *DS 1186(8), 1193(11); WC 1092*.
UCSB: Vernal pool in Isla Vista, 16 Apr 1960, *D.M. Smith, Flinck s.n.*; 100 yards southwest of Del Playa and Camino Corto, 8 May 1967, *Keefe 1728*; Vernal pool on Del Sol site, 20 May 1967, *Keefe 1757*; Drying vernal pool, Isla Vista, 11 May 1973, *Edge 377b*; Behind Isla Vista School, 14 May 1978, *Furukawa 22*; Vernal pool depression on West Campus north of northern boundary of Coal Oil Point Reserve, 22 Mar 1980, *Whitmore s.n.*; West Campus east of Devereux School, 2 May 1980, *Whitmore and Ferren 2175*; Northeast of Devereux School, 15 May 1980, *Ferren 2219*; Ellwood Mesa in field, 30 Apr 1981, *Thomson 31*.
SBBG: Desiccated vernal flat in Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2665*; Mesa of Isla Vista Tract, 15 Jun 1950, *C.F. Smith 2808*; Vernal pool on Del Playa Drive, Isla Vista, 3 May 1967, *Pollard s.n.*; Drying vernal pool, Isla Vista, 11 May 1973, *Edge 377b*.

Juncus phaeocephalus Engelm. var. phaeocephalus. Perennial herb; rare. Observed at CL and across Camino Corto from Del Sol site by W. Ferren.
SBBG: Dry beds of vernal ponds, Isla Vista Tract, 16 Jun 1952, *Pollard s.n.*

Juncus tenuis Willd. var. congestus Engelm. Yard Rush. Perennial herb; rare to scattered; margins of pools and footpaths; *DS 1129(8), 1189(14); CL 1179; MM 1158*.
UCSB: On sandy, grassy bluff around vernal pool in Isla Vista, 5 May 1962, *Breedlove 2664*; 100 yards southwest of Del Playa and Camino Corto, 8 May 1967, *Keefe 1729*; Del Sol site, 20 May 1967, *Keefe 1758*; Northeast junction of Camino Corto and Abrego, 16 May 1978, *Katz 17*; Del Sol site, 26 May 1980, *Roberts 108*; Vacant lot on southeast side of 6823 Del Playa, 13 Apr 1981, *J. Smith 34*; Camino Lindo and Del Playa, 9 May 1981, *Kuenster 183*.

SBBG: Mesa of Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2664*; Camino Lindo on Isla Vista mesa, 22 Mar 1965, *Pollard s.n.*

POACEAE Grass Family

Alopecurus howellii Vasey. Pacific Foxtail. Annual; rare to common; centers of pools; *DS 1127(14); MM 1146.*
UCSB: Sandy, grassy bluff around vernal pool, Isla Vista, 5 May 1962, *Breedlove 2659*; Del Sol site, 16 Apr 1966, *D.M. Smith and Flinck s.n.*; Del Sol site, 20 May 1967, *Keefe 1751*; Del Sol site, 21 May 1978, *Katz 11*; Del Sol site, 31 May 1979, *Fairbank 182*; Del Sol site, 2 Jun 1979, *Corlett 53*; Del Sol site, 9 May 1981, *Kuenster 179*; More Mesa vernal pool, 21 Apr 1982, *Steele 82-125*.
SBBG: Desiccated flats of Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2650*.

Avena barbata Brot. Slender Wild Oat. Annual; common to abundant; outer pool margins and adjacent grassland; introduced; *DS 1344(13); FT 1242; WC 1300.*

Avena fatua L. Wild Oat. Annual; common to abundant; grassland and drying pools; introduced; *DS 1314; CL 1183; EWW 1078a; MM 1157; WC 1096.*

Bromus diandrus Roth. Ripgut Grass. Annual; rare to abundant; pool margins and adjacent grassland; introduced; *DS 1056(10); CL 1172; MM 1153.*

Bromus hordeaceus L. [SY = Bromus mollis L.]. Soft Chess. Annual; scattered to common; pool margins and adjacent grassland; introduced; *DS 1058(10); CL 1177; EWE 1218; EWW 1224; MM 1166.*

Cynodon dactylon (L.) Pers. Bermuda Grass. Perennial; uncommon to abundant; pool margins and adjacent grassland; introduced; *DS 1256(14); CL 1310; FT 1352; EWE 1091; MM 1209.*

Deschampsia danthonioides (Trin.) Munro ex Benth. Annual; rare; vernal flats. Locally extirpated?
UCSB: Vacant lot between Trigo and Sabado Tarde, 150 yards west of Camino del Sur, Isla Vista, 15 Apr 1960, *Haller 1575*.
SBBG: In grassy former vernal pool area of Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2653*.

Distichlis spicata (L.) E. Greene var. spicata. Salt Grass. Perennial; common; pool margins and grasslands; *DS 1250; CL 1269; WC 1097.*
UCSB: Ellwood Mesa in hollow with Baccharis pilularis, 13 Jun 1981, *Thomson 105*.

Festuca arundinacea Schreb. Perennial; introduced; observed by W. Ferren at Del Sol in 1987, none collected.

Gastridium ventricosum (Gouan) Schinz & Thell. Nitgrass. Annual; introduced; observed at Del Sol by W. Ferren.
UCSB: Ellwood Mesa in field, 26 May 1981, *Thomson 85*.

Heleochloa schoenoides (L.) Horst. Annual; common only at West Campus; center of moist or desiccated pools; introduced; *WC 1339*.

Hordeum brachyantherum Nevski. Meadow Barley. Perennial; rare to abundant; deeper parts of pools; *DS 1051(10), 1123(14); CL 1170; EWE 1084; WC 1233.*
UCSB: Camino Corto & Trigo, 2 Apr 1961, *Keefe 155*; Del Sol site, *Keefe 1726*; 100 yards southwest of Del Playa and Camino Corto, 8 May 1967, *Keefe 1726*; Del Sol site, 20 May 1967, *Keefe 1755, 1756*; West Campus, north slough finger, 11 May 1980, *Reisentz 80-107*; Del Sol site, 20 Apr 1981, *Kuenster 175*; Ellwood Mesa Pool A, 30 Apr 1981, *Thomson 27 & 28*; Ellwood Mesa Pool A, 5 May 1981, *Thomson 49*.
SBBG: On mesa above ocean of Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2662*; Del Playa near Camino Lindo intersection, 22 Mar 1965, *Pollard s.n.*; Vernal pool on Del Playa Drive, Isla Vista, 3 May 1967, *Pollard s.n.*; Meadow on El Colegio Road, Isla Vista, 3 May 1967, *Pollard s.n.*

Hordeum californicum Covas & Stebbins. California Barley. Perennial; rare to common; outer pool margins, grassland, and footpath margins.
UCSB: 100 meters west of Camino Corto on Del Playa, 17 May 1976, *Mutter 43*; Vernal pool fields, west end of Del Playa, 30 May 1979, *Rafferty 78*; Del Sol site, 31 May 1979, *Fairbanks 184*; Southern tip of golf course west of Storke Road opposite Francisco Torres Dormitory, 18 Apr 1980, *D. Roberts 3041*; Head of northern slough finger, northeast of Devereux School, 15 May 1980, *Ferren 2221*; Del Sol site, 20 Apr 1981, *Kuenster 174*; Ellwood Mesa Pool L, 24 Apr 1981, *Thomson 34*; Del Sol site, 31 May 1983, *Strong 108*.

Hordeum geniculatum Allioni. Mediterranean Barley. Annual; rare to common; center to margins of moist or desiccated pools; introduced; *DS 1190(14), 1195(8); CL 1178; FT 1241; EWE 1212; EWW 1221; MM 1155; WC 1232.*

Hordeum murinum L. [including H. leporinum Link and H. glaucum Steud.]. Annual; common; grassland; introduced; *DS 1121; MM 1167.*

Lolium multiflorum Lam. [SY= L. perenne subsp. multiflorum (Lam.) Husnot]. Italian Ryegrass. Annual; abundant; pools, pool margins and grassland; introduced; *DS 1121; CL 1169; FT 1239; EWE 1210; EWW 1222; MM 1148; WC 1094.*

Oryzopsis miliacea (L.) Benth. Rice Grass. Perennial; rare near pools but an otherwise common species; grassland; introduced; *DS 1282.*

Phalaris aquatica Nees ex Trin. Harding Grass. Perennial; rare to abundant; pool margins and adjacent grassland; introduced; *EWE 1217; MM 1206.*

Phalaris lemmonii Vasey. Annual; rare to common; center of pools; *DS 1126(14); 1191(14); CL 1203; EWE 1215; MM 1149, 1207.*
UCSB: Del Sol site, 16 Apr 1966, *Flinck & D.M. Smith s.n.*; 100 yards southwest of Del Playa and Camino Corto, 8 May 1967, *Keefe 1732*; Del Sol site, 31 May 1979, *Fairbank 183*; Del Sol site, 2 Jun 1979, *Corlett 52*; Ellwood Mesa Pool M, 7 May 1981, *Thomson 51*; Del Sol site, 9 May 1981, *Kuenster 178*; More Mesa vernal pool, 21 Apr 1982, *Steele 82-124*.
SBBG: Desiccated vernal flat of Isla Vista Tract, 20 Apr 1950, *C.F. Smith 2654*; Vacant lot between Trigo and Sabado Tarde, 150 yards west of Camino del Sur, Isla Vista, 15 Apr 1960, *Haller 1573*; Edge of vernal pool on Del Playa Drive, Isla Vista mesa, 3 May 1967, *Pollard s.n.*

Phalaris minor Retz. Mediterranean Canary Grass. Annual; rare; grassland; introduced; *CL 1182.*

Phalaris paradoxa L. Observed in grazed vernal flat by W. Ferren on West Campus in 1980.

Poa annua L. Annual Bluegrass. Annual; common; along footpaths and in disturbed sites in pools; introduced; *DS 1348(10); EWE 1211; EWW 1072a.*

Polypogon interruptus HBK. Annual; common; center to margins of pools; introduced; *DS 1200(14); CL 1202; EWE 1214; EWW 1220.*

Polypogon monspeliensis (L.) Desf. Rabbitsfoot Grass. Annual; uncommon; pool margins; introduced; *EWW 1072; MM 1261.*

Stipa cernua Steb. & Löve. Nodding Needle Grass. Perennial herb; locally common; not in pools; *CL 1267.*

Stipa pulchra Hitchc. Purple Needlegrass. Perennial herb; common in grassland on Ellwood Mesa, expected near pools.

Vulpia bromoides (L.) S.F. Gray. Annual; occasional to abundant; grassland and pool margins; introduced; *DS 1059(10), 1194(5); EWW 1074, 1223.*

Restoration and Creation of

APPENDIX IV: "Del Sol Open Space and Vernal Pool Reserve" (brochure)

APPENDIX V: "Vernal Pools of the Del Sol Reserve" (booklet)

Restoration and Creation of Vernal Pools: Cookbook Recipies or Complex Science?

Wayne R. Ferren Jr. and Elihu M. Gevirtz

Reprinted from: Vernal Pool Plants--Their Habitat and Biology. Studies from the Herbarium, CSU Chico, 1990

Vernal Pools of the Del Sol Reserve

By David A. Pritchett and Wayne R. Ferren Jr.
Illustrations by Kathryn Simpson

Isla Vista Recreation and Park District
Santa Barbara County, California

This booklet was published in January 1988 with funds provided by grant no. 85-073-86-020 from the California State Coastal Conservancy to the Isla Vista Recreation and Park District.
Photographs by Wayne Ferren and David Pritchett, who are affiliated with the UCSB Herbarium, Department of Biological Sciences, University of California, Santa Barbara.

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COVER: A diverse assemblage of plants is evident in the spring at a Santa Barbara vernal pool.
COVER INSET: Visitors examine closely one of the larger vernal pools at the Del Sol Reserve.

CONTENTS

Spike-rush (left) and coyote-thistle (right) are common plants of the Del Sol vernal pools.

What Are Vernal Pools?

Vernal pools are a particular kind of ecosystem. They form as a result of a distinctive climate, topography, and soil, and are distinguished by the organisms within them. The climate must have mild winter temperatures and a summer drought. Such a "Mediterranean climate" occurs in several regions of the world, including most of California. The topography of a vernal pool must be a shallow depression that will catch water from the winter rains. The soil of a vernal pool must contain an impermeable layer, such as clay layer or mineral layer, and, in conjunction with proper topography, must allow flooding for several weeks or months during the winter wet season.

The organisms of vernal pools are the ultimate indicator of the vernal pool habitat. The physical conditions in a vernal pool provide a particular habitat for some plants adapted to survive nowhere else. Some animal species also may be restricted to vernal pools. The presence of any of these specialized plants and animals distinguishes vernal pools from other types of aquatic ecosystems. In brief, a vernal pool is a specific ecosystem having organisms restricted to special habitats that flood temporarily in the winter and early spring, but are dry the remainder of the year.

Life in a Vernal Pool

The annual cycle of flooding and drying in a vernal pool creates an environment where few species can survive. Species that occur in permanently wet areas such as a freshwater marsh cannot tolerate the long drought when the pool is dry. Conversely, species that occur in dry habitats such as an annual grassland, an ecosystem that seldom or never floods, cannot withstand the prolonged inundation when the pool is wet. Species that do persist in vernal pools, however, are unique because they can grow, reproduce, and survive — as a seed, egg, or dormant adult — in these habitats when most other plants and animals cannot endure the environmental extremes. Within a vernal pool depression, different plant species may be most abundant at different elevations. Some species, though, grow along a wide elevational gradient, whereas others grow only within a narrow elevational range.

⅔x

The buckeye butterfly *(Junonia coenia)* is widespread, and often is found in vernal pools.

One example of a species adapted for life in a vernal pool is the annual plant wooly-heads *(Psilocarpus brevissimus)*. It has floating seeds that disperse throughout the vernal pool as the water level rises. The plant seldom germinates and grows to maturity unless pools flood with water. Native plants such as wooly-heads, which have specific adaptations for surviving in a vernal pool, usually cannot grow in any other type of habitat. In fact, some vernal pool plants are rare or endangered because they naturally occur in only a few vernal pools, or because they occur in pools that may be endangered by agricultural or urban expansion. For example, in Isla Vista, a species of goldfields *(Lasthenia conjugens)* was last observed in 1950, but it is now no longer found in the area. In addition to the native species occurring in vernal pools, other vernal pool plants include non-native species, such as rabbitsfoot grass *(Polypogon monspeliensis)*, that have become naturalized members of the ecosystem.

Four Environments in One Ecosystem

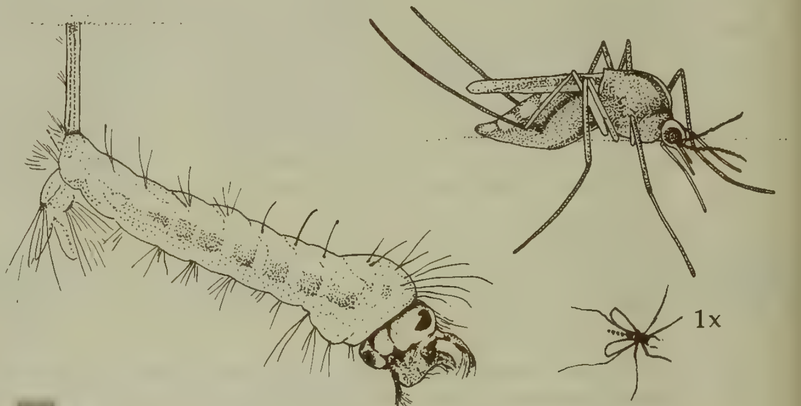
From an ecological point of view, the annual cycle of flooding and drying creates four distinct environments in a vernal pool at different times of the year. Only during the winter and early spring months do vernal pools typically have pools of water with characteristic species apparent. At other times of the year, the pools are dry, and various species that occur in other types of habitats may be more abundant.

During late autumn, when the first rains fall, the soil becomes saturated, and seeds of annual plants germinate. Shoots of perennial plants such as the spike-rushes *(Eleocharis* spp.*)* resprout after dying back during the summer drought. The vernal pool may have a dense carpet of new growth.

At the height of the winter rains, the pools fill to their maximum. Vernal pool animals flourish: aquatic insects and zooplankton swarm in the water, ducks visit to feed, and Pacific treefrogs *(Pseudacris regilla)* breed and lay eggs after a long chorus of croaking. Non-aquatic plants such as filaree *(Erodium* spp.*)*, which colonize the pool shortly before it floods, die after prolonged submergence. Species of coyote-thistle *(Eryngium* spp.*)* sprout long tubular leaves during this aquatic phase of their life history.

During late winter and spring, when the water level recedes, most of the vernal pool plants mature to full flowering. Different species often occupy distinct zones within the vernal pool depression, creating concentric rings of various flowering colors. This show of plants in the spring, when the vegetation outside of the pool is usually dry and dying, is why "vernal" pools have their name. Aquatic animals by this time of year have either died and laid eggs or become dormant.

From late spring to early autumn, a period of extended drought, vernal pools are dry, and little life is apparent. The soil may have deep cracks. However, various species of tarweed *(Hemizonia* spp.*)*, a common annual plant maturing in the summer, may be abundant in the dried basins of the pools. In early summer, coyote-thistle has lost its leaves, and instead produces spiny heads of minute flowers.



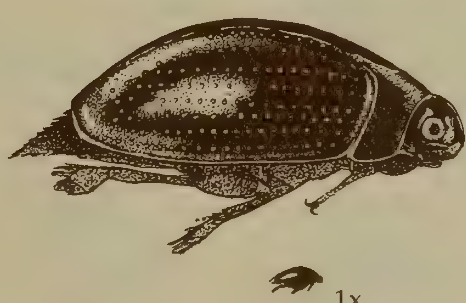
The *Culex* mosquito is aquatic as a larva, and can become abundant in Del Sol vernal pools. Adults are infamous.

Vernal Pools in California

Vernal pools occur throughout the State where conditions are favorable. Many areas in California with a Mediterranean climate, gently undulating topography, and impermeable soil have or once had vernal pools. They are most common along the eastern Central Valley at the lower foothills of the Sierra Nevada. They also occur in other parts of the Central Valley, as near Sacramento. Lava flows and volcanic mudflows in north-central California near Chico and in southern California near Riverside also have vernal pools. Others are located in the eastern valleys of the mountains between San Luis Obispo and Monterey. In addition to these interior locations, vernal pools exist on many terraces and mesas along the California coast. They are very numerous, for instance, in the San Diego region.

Vernal pools also occur outside of California. Pools similar to those in California exist in south-central Oregon and north-coastal Baja California. Other temporary pools with specialized organisms exist at many places throughout the world, and many of these habitats could be considered types of vernal pools.

Distribution of vernal pools in California.



The predaceous water beetle *Aqabus* sp. occurs in vernal pools and many other aquatic habitats.

Vernal Pools at Santa Barbara

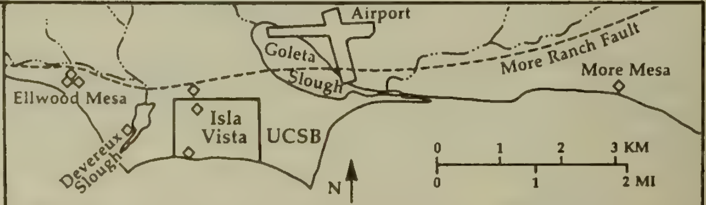
Vernal pools of the Santa Barbara area occur immediately west of the city at the coastal sites of More, Isla Vista, and Ellwood mesas. Each of these sites sits on the south side of the More Ranch Fault, a geologic feature along which the coastal zone has been uplifted to create relatively flat marine terraces. The vernal pools have formed on this flat topography at sites having minor depressions and an impermeable clay layer in the soil.

More Mesa has one vernal pool, which sits above the ocean bluff at the southeastern corner of the mesa. A dense stand of Harding grass *(Phalaris aquatica)*, a robust naturalized plant, surrounds the pool, but several uncommon vernal pool species occur within it. Treefrogs are abundant at this vernal pool.

Isla Vista Mesa has 20 vernal pools, all but five of which are located at the Del Sol Reserve. Two not on the Reserve are at the south (ocean) side of Del Playa Drive near Camino Lindo. One of these is at the County Park Annex, a property of the Park District. These two pools on Del Playa Drive are the southernmost range for the plant *Eryngium armatum,* a coyote-thistle. Other vernal pools exist at the areas west of Camino Corto and north of Francisco Torres dormitory. In the dry season especially, dense grasses dominate most vernal pools in Isla Vista. Before urbanization in the 1960's, vernal pools were very common throughout the southern half of Isla Vista.

Ellwood Mesa, also known as Santa Barbara Shores, includes 17 vernal pools scattered over 80 hectares (200 acres). The vegetation of these pools is low, and has a high diversity of species. A history of horse grazing, or the particular soil there, may suppress many weedy species, allowing the high diversity. In 1985, near Ellwood Mesa on UCSB property west of Devereux Slough, a few vernal pools were created as an experimental effort to mitigate the destruction of vernal pools in the area immediately west of Isla Vista.

Vernal pools also occur in northern Santa Barbara County, such as in the Santa Rita Valley east of Lompoc. Northwest of Lompoc at Vandenberg Air Force Base, other vernal pools occur in low spots among old and stabilized sand dunes. Several of these support the coyote-thistle *Eryngium armatum* and plants not found in the Santa Barbara area.



Locations of vernal pools (◇) in the Santa Barbara area.

Vernal Pools at the Del Sol Reserve

The Del Sol Vernal Pool Reserve is a parcel 4.8 hectares (11.8 acres) in area located at the southeastern corner of El Colegio Road and Camino Corto. The property is owned by the Isla Vista Recreation and Park District. In addition to vernal pools, it also includes coastal scrub, which is represented by coyote bush *(Baccharis pilularis)*, and grassland.

Fifteen vernal pools exist at the site, some of which are quite shallow and are dominated by naturalized ryegrass *(Lolium multiflorum)*. The shallow vernal pools do not undergo enough flooding to support large populations of native plants such as popcorn flower *(Plagiobothrys undulatus)* or wooly-heads *(Psilocarphus brevissimus)*, two species that grow only in vernal pools. Nevertheless, they are important aquatic habitats because many animals characteristic of vernal pools occur there.

The deeper Del Sol vernal pools that undergo prolonged flooding and support large numbers of indicator species are more numerous than the shallow pools. At their margins, the deeper pools typically support much ryegrass, but at their centers, the prolonged flooding provides conditions that support vernal pool plants such as coyote-thistle *(Eryngium vaseyi)* and pillwort *(Pilularia americana)*. During late spring and summer, dense annual grasses dominate most of the vegetation of the Del Sol pools and other pools in Isla Vista.

Backswimmers *(Notonecta* sp.*)* are widespread aquatic carnivores that swim upside down.

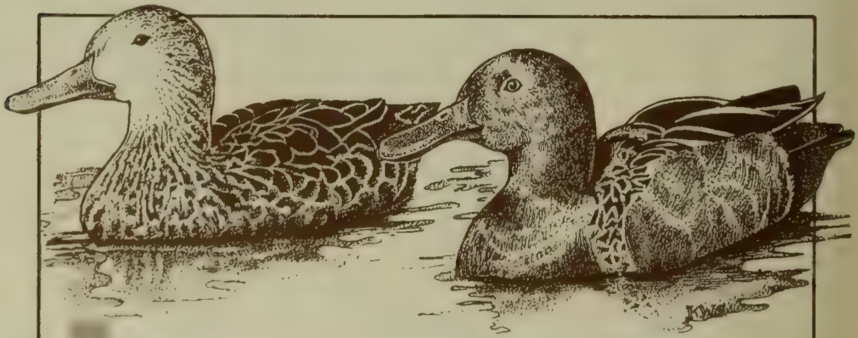
Origin of the Del Sol Vernal Pools

The origin of the Del Sol vernal pools is attributed to several processes. The bigger pools probably were once seasonal seeps at the upper ends of troughs draining into Goleta and Devereux sloughs. Construction of the nearby streets isolated the habitats to form enclosed basins that are now the vernal pools. The seeps apparently functioned like vernal pools, and probably supported similar organisms. Other pools may have been isolated depressions that were connected to the troughs only during maximal flooding.

The pools that are presently crossed by footpaths very likely are expanding in depth and width as people walk through and around them. The soil also is becoming compacted, and retains more water. Although the location in a footpath has a high potential for disturbance, the organisms in these vernal pools are diverse because people avoid these flooded areas during the wet winter. At this time of year, the vernal pool environment is most susceptible to disturbances affecting the soft mud and fragile plant seedlings.

Enhancement, Restoration, and Creation of Vernal Pools

In 1986, some of the Del Sol vernal pools were enhanced, restored, or created, three managerial techniques often practiced on aquatic ecosystems. This work was funded by a grant from the California State Coastal Conservancy to the Park District. In addition to modification and creation of the vernal pools, the project included removal of litter and debris, and the establishment of a low barricade around the site's perimeter to prevent vehicular access. To promote public awareness of the environmental resources at the Reserve, interpretive signs were installed, and this booklet and a pamphlet describing the site were published. The staff of the UCSB Herbarium assisted the Park District with most aspects of the project.



Cinnamon teal *(Anas cyanoptera)* occasionally visit Del Sol vernal pools during the winter.

One of the larger Del Sol vernal pools was *enhanced* by constructing two small dams to prevent water from draining out of the pool through ditches dug for mosquito abatement. Because it now floods to a greater depth, weedy species such as ryegrass, which have been some of the dominant plants within the vernal pool, should decrease in abundance with the increase in the depth and duration of flooding. Conversely, native vernal pool species should expand in abundance with an increase in flooding.

Two vernal pools were *restored* by removing mounds of soil, concrete, and other debris that had been dumped into them since the 1960's. Material was excavated with large and small tractors, and was mounded on top of an old parking lot, which is now a landscaped picnic and observation area. After excavation, the restored vernal pools were nearly tripled in size, and should support a greater population of native species.

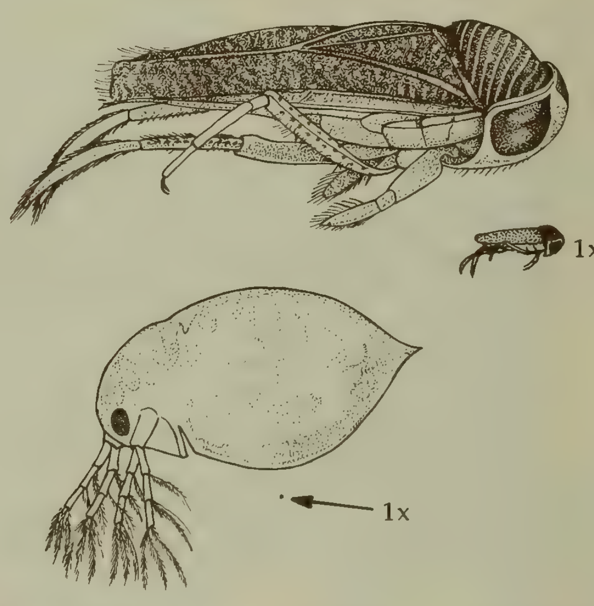
Six vernal pools were *created* by excavating depressions into a dry grassland in the northeastern section of the Reserve. Three of them were inoculated with seeds obtained from surface scrapings of natural vernal pools at Ellwood Mesa. The other three were not inoculated, thus providing an experimental comparison. Excavation of both the created and restored vernal pools did not penetrate the impermeable clay layer in the soil.

A small tractor excavates one of the created Del Sol vernal pools.

Vernal Pool Organisms

The flora and fauna of the Del Sol vernal pools, as in all other vernal pools, include many groups from both the plant and animal kingdoms. A fern is included, as are many different monocots and dicots, which are the two categories of flowering plants. The list on page 11 includes the vascular plant species of the Del Sol pools. Most of these species can grow in habitats other than vernal pools, but those restricted to vernal pools in general or to vernal pools when the plants occur in the Santa Barbara area are noted accordingly. The fauna of the vernal pools is understood poorly, however, and no complete list is yet available.

No species presently listed by regulatory agencies as threatened, rare, or endangered occur in any vernal pools of the Santa Barbara area. Nevertheless, preservation of the vernal pool habitats and the organisms within them is extremely important to perpetuate regionally rare species such as pillwort *(Pilularia americana)* or Pacific foxtail *(Alopecurus howellii)*, as well as the entire diversity of life in the local pools. A diversity of life can provide aesthetic satisfaction as well as economic gain. For instance, the seeds of meadowfoam *(Limnanthes* spp.*)*, a vernal pool plant from other areas in California, produces an oil that may be a substitute for the financially and environmentally expensive oil from sperm whales.



Above: Water boatmen *(Corisella* sp.*)* are omnivorous, and occur in many types of pools.
Below: The water flea *Daphnia magna* is a very small crustacean that is an important source of food for larger vernal pool animals.

Plant Species Occurring in Vernal Pools of the Del Sol Reserve

Ferns:
Marsileaceae, marsilea family
- * *Pilularia americana,* pillwort

Monocots:
Cyperaceae, sedge family
- * *Eleocharis acicularis,* needle spike-rush
- + *E. palustris,* spike-rush

Juncaceae, rush family
- + *Juncus bufonius,* toad rush
- * *J. tenuis,* yard rush

Poaceae, grass family
- * *Alopecurus howellii,* Pacific foxtail
- † *Avena barbata,* slender wild oat
- † *A. fatua,* wild oat
- † *Bromus diandrus,* ripgut grass
- † *B. mollis,* soft chess
- † *Cynodon dactylon,* Bermuda grass
- o *Distichlis spicata,* salt grass
- * *Hordeum brachyantherum,* meadow barley
- † *H. geniculatum,* Mediterranean barley
- † *H. leporinum,* foxtail
- † *Lolium multiflorum,* ryegrass
- * *Phalaris lemmonii,* lemmon canarygrass
- † *Poa annua,* annual bluegrass
- + *Polypogon monspeliensis,* rabbitsfoot grass
- † *Vulpia myuros,* rattail fescue

Dicots:
Apiaceae, celery family
- * *Eryngium vaseyi,* coyote-thistle

Asteraceae, sunflower family
- †+ *Cotula coronopifolia,* brass buttons
- * *Hemizonia australis,* tarweed
- o *H. fasciculata,* tarweed
- † *Lactuca serriola,* prickly lettuce
- * *Psilocarphus brevissimus,* wooly-heads
- † *Sonchus asper,* prickly sow-thistle
- † *S. oleraceus,* common sow-thistle

Boraginaceae, borage family
- * *Plagiobothrys undulatus* popcorn flower

Callitricaceae, starwort family
- * *Callitriche marginata,* wallow starwort

Caryophyllaceae, pink family
- † *Spergula arvensis,* corn spurry
- † *Spergularia bocconii,* sand spurry

Convolvulaceae, morning glory family
- † *Convolvulus arvensis,* bindweed

Crassulaceae, stonecrop family
- * *Crassula aquatica,* stonecrop

Elatinaceae, waterwort family
- * *Elatine brachysperma,* waterwort

Euphorbiaceae, spurge family
- o *Eremocarpus setigerus,* dove weed

Fabaceae, pea family
- † *Vicia angustifolia,* narrowleaf vetch
- † *V. benghalensis,* purple vetch
- † *V. sativa,* common vetch

Geraniaceae, geranium family
- † *Erodium botrys,* broadleaf filaree
- † *E. cicutarium,* redstem filaree
- † *E. moschatum,* whitestem filaree

Lythraceae, loosestrife family
- + *Lythrum hyssopifolia,* loosestrife

Plantaginaceae, plantain family
- † *Plantago lanceolata,* English plantain

Polygonaceae, buckwheat family
- † *Polygonum aviculare,* common knotweed
- † *Rumex angiocarpus,* sheep sorrel
- †+ *R. crispus,* curly dock

Portulacaceae, purslane family
- o *Calandrinia ciliata,* red maids

Primulaceae, primrose family
- † *Anagallis arvensis,* scarlet pimpernel
- * *Centunculus minimus,* common chaffweed

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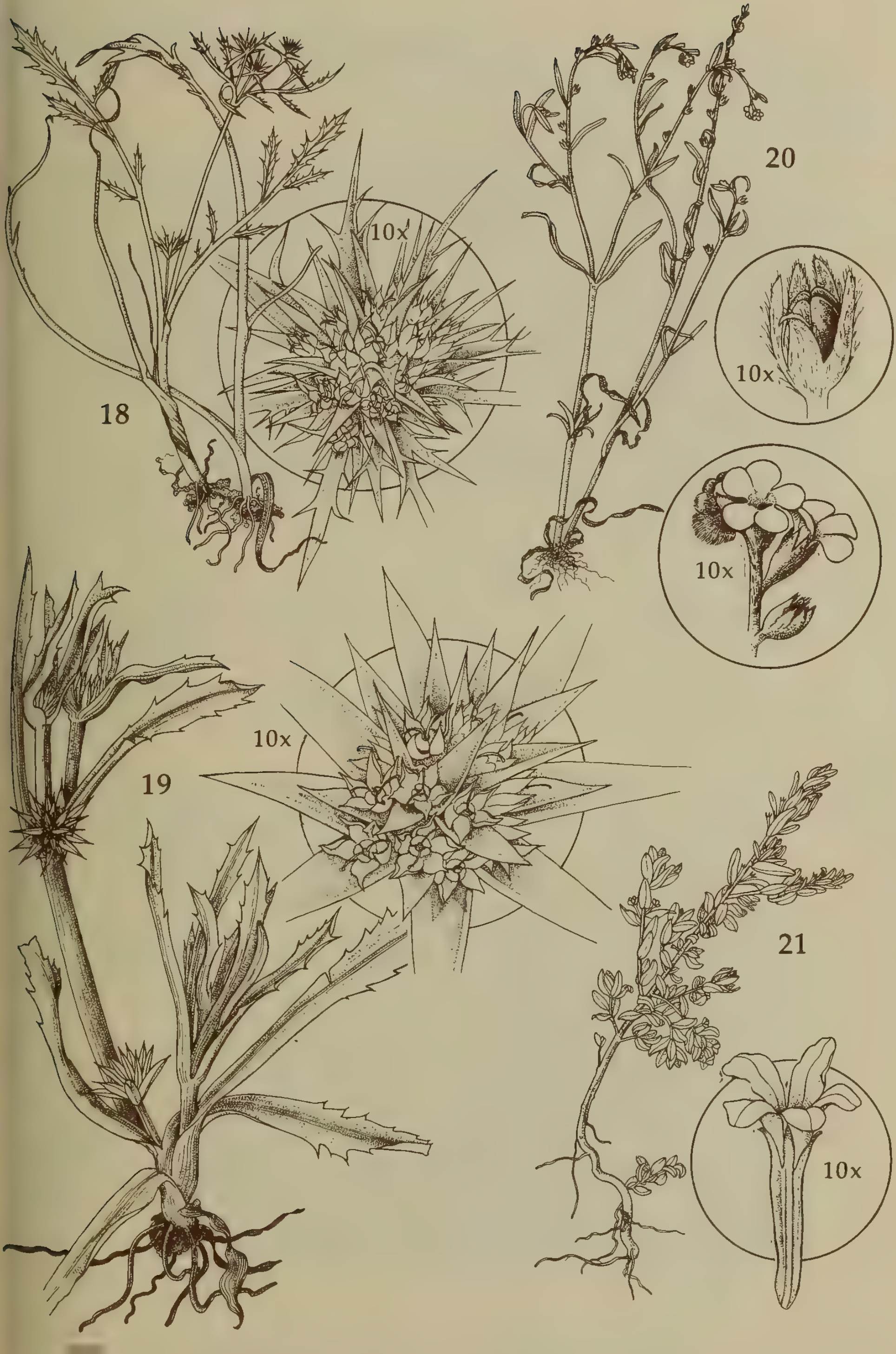
* Species restricted to vernal pools in general or to vernal pools when the plants occur in the Santa Barbara area.
\+ Species restricted to vernal pools and other aquatic habitats.
† Naturalized, non-native species.
o Native species occurring in many habitats.

Vernal pool plants surveyed in 1987 by Holly C. Forbes.

1. blue-eyed grass *(Sisyrinchium bellum)*, 2. dwarf brodiaea *(Brodiaea jolonensis)*, 3. brass buttons *(Cotula coronopifolia)*, 4. wallow starwort *(Callitriche marginata)*, 5. stonecrop *(Crassula aquatica)*, 6. waterwort *(Elatine brachysperma)*, 7. wooly-heads *(Psilocarphus brevissimus)*. 1 and 2 show plants that grow on the margins and outside of vernal pools. Illustrations are ⅔ actual size.

8. meadow barley *(Hordeum brachyantherum)*, 9. ryegrass *(Lolium multiflorum)*, 10. Pacific foxtail *(Alopecurus howellii)*, 11. Mediterranean barley *(Hordeum geniculatum)*, 12. Lemmon canarygrass *(Phalaris lemmonii)*. Illustrations are ⅔ actual size.

13. toad rush *(Juncus bufonius)*, 14. spike-rush *(Eleocharis acicularis)*, 15. yard rush *(Juncus tenuis)*, 16. pillwort *(Pilularia americana)*, 17. spike-rush *(Eleocharis palustris)*. Illustrations are ⅔ actual size.



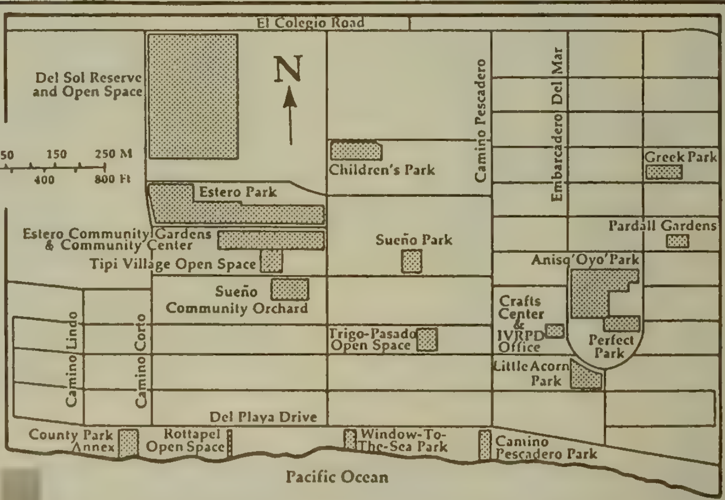
18. coyote-thistle *(Eryngium vaseyi)*, 19. coyote-thistle *(Eryngium armatum)*, 20. popcorn flower *(Plagiobothrys undulatus)*, 21. loosestrife *(Lythrum hyssopifolia)*. Illustrations are ⅔ actual size.

The Isla Vista Recreation and Park District

Established in 1972, the Isla Vista Recreation and Park District (IVRPD) is a governmental body with an elected Board of Directors and a professional support staff. According to its Master Plan, the purpose of the District is "to enhance, improve, and protect the quality of life in the community" and to "contribute to the health, enjoyment, and thriving satisfaction of the people, and to the safety, cleanliness, and beauty of the environment, its flora and its fauna." The District is financed primarily through bonds and property taxes in Isla Vista. IVRPD endeavors to preserve open space in Isla Vista through the acquisition and maintenance of land as parks, gardens, or nature reserves.

Parcels owned by the District are managed as one of three categories: Natural Open Space, Improved Park, or Developed Park. A Natural Open Space, such as Del Sol Open Space and Reserve, has undergone minimal disturbance or development, and is characterized by native or naturalized flora and fauna. An Improved Park, such as Anisq' Oyo' Park or Children's Park, consists mostly of landscaped vegetation and natural land forms in conjunction with buildings, walkways, or other structures. A Developed Park, such as the Craft Center or Estero Community Center, includes mostly various buildings and structures with minimal open space and vegetation.

In addition to the preservation of open space in Isla Vista, the promotion of recreation and cultural arts also is an important goal of the District. Annual festivals, for instance, are sponsored in the fall and spring. The Park District office is located at 961 Embarcadero del Mar, Isla Vista, CA 93117, telephone 805-968-2017.



Parcels within the Isla Vista Recreation and Park District.

A natural vernal pool at Del Playa Drive and Camino Lindo in Isla Vista. Santa Cruz Island is visible on horizon.

At an Ellwood Mesa vernal pool, plants within are beginning to flower, whereas plants outside already have become dormant.

Restoration and Creation of Vernal Pools: Cookbook Recipes or Complex Science?

WAYNE R. FERREN Jr.
ELIHU M. GEVIRTZ

Abstract

Twenty-one projects or activities in California have involved the manipulation of vernal pool habitat as a result of experiments, agency-required mitigation, pre-construction pilot projects, or coincidental habitat alteration. Should the potentially successful efforts to manipulate the environment be based upon simple "cookbook recipes" (e.g. excavation + seed + water = vernal pool), or should they also be the result of complex scientific and technological processes? Various criteria, such as hydrology, species richness, vegetative cover, and target species, have been used to assess the "success" of restoration or creation of vernal pools. At Del Sol Reserve in Santa Barbara County, California, short-term (three yr) post-construction monitoring and analysis revealed that restoration and creation of pools has provided habitat for native vernal pool plants and animals and that vegetative patterns approximate those of natural habitat. Plant species cover and abundance, however, are not yet comparable to those of regional natural pools. Many attempts to assess the "success" of vernal pool restoration and creation in California have not used pre-determined performance criteria. Those that do, usually describe the ability of a project to achieve project-oriented goals rather than criteria that address the re-creation of functional values in addition to an overall resemblance to natural vernal pool ecosystems. A scientific approach to the development of hypotheses, performance criteria, the measurement of ecosystem response during rigorous monitoring programs, and the analysis or interpretation of results is essential to accurately assess each formula or "recipe" for restoration or creation and to estimate the success of habitat re-creation. However, the approach to date has been minimal, and has provided no conclusive evidence that vernal pool habitat has been restored or created in a manner that resulted in "functional values" (e.g. food chain support) of, or overall "resemblance" (e.g. visual appearance) to, the observed variability of natural vernal pools.

Introduction

Aspects of the intriguing complexity of vernal pools have received insightful treatment and discussion. We have heard much about what we know and don't know regarding the physical and biological attributes of these environmentally sensitive ecosytems. The majority of vernal pools in California, however, have been destroyed or degraded as a result of impacts from agricultural development and urbanization (Holland, 1978; Zedler, 1987). Fortunately, legislation, agency staffs and policies, scientists,

consultants, and the increasingly concerned public are brought together in the current movement for habitat protection and restoration, and for the mitigation of impacts. There is an urgent need to apply what we have learned about the remaining natural vernal pools, through experimental projects, to the restoration of degraded pools and the potential creation of new pools.

Much of the experimental effort to manipulate habitats, however, is driven by agency-required mitigation plans and developer-sponsored pre-mitigation experiments. This situation of required compensation for lost habitats provokes the question: *Are we prepared to design and implement mitigation programs with realistic performance criteria when we often know little about the natural systems we plan to replicate?* At this point in the evolution of our concern for the replication of the pre-disturbance natural values of vernal pools, we also need to consider a second question: *Should the potentially successful efforts to manipulate the environment be based only upon simple "cookbook recipes" (e.g. excavation + seed + water = vernal pool), or should they also be the result of complex scientific and technological processes?* The difference between these approaches is the ability of science and technology to evaluate the effectiveness of the effort by comparing manipulated habitat with undisturbed habitat. In this paper, we suggest an answer to this second question by (1) examining some of the criteria we should consider during the restoration and creation process, (2) discussing several existing vernal pool projects in California, (3) giving a detailed review of a restoration and creation project in the Santa Barbara area, and (4) reviewing potential problems and the need for adequate planning and management of restored and created habitats.

Criteria for the Restoration and Creation Process

Several important questions should be addressed when vernal pool and other habitat restoration and creation projects are proposed. Perhaps the most important of these questions is, *What is "successful" restoration and creation and how should it be measured?* Various physical and biological criteria have been used to measure success. For example, various federal agencies have required the Laguna Creek Assessment District in Sacramento County to re-create vernal pools of similar or higher habitat values as a mitigation for impacts that occurred as a result of a District project (Zentner & Zentner, 1988). A five-year monitoring program was implemented to evaluate the "success" of all restoration efforts. Post-project monitoring activities adopted for this project include measurements or observations of water depth and flooding frequency, plant species richness and cover, invertebrate species richness and abundance, and bird species richness and activities (Zentner, 1989). Elements of this mitigation program found not to meet "specific

performance criteria" are required to be "corrected" by the District (Zentner & Zentner, 1988).

Other examples of the use and measurement of project "success" are usually more limited forms of those measurements or observations proposed above, and include: (1) the monitoring of target species such as the endangered plant *Pogogyne abramsii* J. T. Howell in restored and created pools in San Diego County (Scheidlinger, 1985, 1988; Bauder, 1989a, b; Zedler and Black, in press, 1989b), (2) the comparison of hydrological conditions in natural and created pools at the Sunrise-Douglas Property in Sacramento County (Stromberg et al., 1989), and (3) the comparison of hydrological conditions and plant species richness and cover in natural, restored, and created pools in Santa Barbara County (Ferren and Pritchett, 1988).

Post-construction performance criteria and monitoring techniques generally used in California usually address the broad question: *Do restored or created vernal pools "resemble" natural pools?* Examples of habitat resemblance (and also a test for "success") have included the restoration or creation of characteristic hydrologic regimes, the establishment of target species, and the measure of species richness or cover. In general, monitoring has focused on the post-construction performance of particular species or physical attributes. Although application of these success standards may take into account regional environmental variability and significant components of a vernal pool community, it usually fails to present an acceptable level of understanding of how the community functions or what its relationship is to the larger ecosystem in which it occurs. Thus, these individual and often limited standards of success also avoid the more complex question: *How does the restored or created pool (or system of pools) function as a self-sustaining community and what are its functional values in the broader, regional ecosystem such as grassland, chaparral, or woodland?* A "self-sustaining" community such as a vernal pool is one that supports natural values and does not require assistance (e.g. application of water, removal of invasive exotics, and transplantation of native organisms) to persist indefinitely. Examples of the "functional values" of vernal pools include: (1) food chain support (e.g. the existence of various primary producers, herbivores, detritivores, and carnivores) that depend on the vernal pool community, (2) biological patterns (e.g. vegetation patterns associated with physical parameters, (3) ecological role (e.g. raptor foraging sites during desiccated periods) of these seasonal wetlands within the regional ecosystem in which they occur, (4) breeding and rearing areas (e.g. for amphibians such as tree frogs), and (5) habitat values for narrowly-restricted species (e.g. vernal pool endemics).

Only after comprehensive and often lengthy monitoring of physical and biological characteristics and functional values of manipulated and undisturbed natural pools in a region can we then ask the insightful question:

Do restored or created vernal pools have the same functional values as natural vernal pools? This question is difficult to answer because we generally know little regarding the functional values of vernal pool systems and the variability of these values within and among regions that support vernal pools. It is essential, however, to answer this question during the pre- and post-construction evaluation of a project, because compensation for lost resources must result in an artificial system that not only "resembles" attributes of a natural system, but also one that must function within the variability of similar natural vernal pools. Zedler and Black (1989b) recently emphasized at a vernal pool symposium in Sacramento that one goal of vernal pool creation is the establishment of a "self-sustaining ecosystem" that has species abundance and composition within the range of a natural system, maintains target species, functions as a natural system, and maximizes aesthetics. Such a goal is consistent with our criteria for the establishment of restored or created ecosystem values.

We return to the question: *Cookbook recipes or complex science?*. Because two fundamental aspects of science are (1) the gathering of data to describe a set of existing conditions, and (2) the formulation and testing of hypotheses, we suggest that if the process of restoration and creation of ecosystems is science, then it should include both of these aspects. Given that mitigation should have rigorous performance criteria and that scientific experimentation must be based upon a thorough collection of data that describe existing conditions and rigorously test hypotheses, we propose the manipulation of vernal pools in California be analyzed in the context of the following hypothesis: *Vernal pools can be restored or created (1) to resemble the physical and biological attributes of natural pools, (2) to provide the functional values of natural vernal pools, and (3) to be self-sustaining ecosystems.*

This hypothesis requires further refinement, however, because our expanding knowledge of California vernal pools, evidenced by presentations at several recent symposia, has revealed the great diversity of habitats that are grouped within the designation "vernal pool". These habitats include, for example, (1) coastal marine terrace grassland seasonal seeps and drainages, (2) decomposed sandstone chaparral seasonal pools and drainages, (3) foothill basin seasonal pools, (4) alluvial valley grassland seasonal pools and drainages, and (5) volcanic mudflow seasonal pools, seeps, and drainages. One concern to come from our increased knowledge is that observations on or conclusions drawn from the results of a habitat manipulation experiment, or mitigation for impacts to one type of vernal pool habitat, may not be transferable to another region. Thus, procedures to restore or create vernal pools and criteria to measure the success of a project may be relevant to only one type of habitat within one region. Other topics of concern include regional differences in water chemistry (such as salinity, pH, and total conductivity) and vegetative cover and species richness in natural pools (e.g.

higher perennial cover and lower species richness of Santa Barbara pools versus lower perennial cover and higher species richness of Riverside and San Diego pools), and unresolved systematics problems (e.g. within the genus *Eryngium* and many groups of invertebrates) that make comparisons of results among projects inconclusive. Zedler and Black (1989a) also emphasize five basic elements to consider in creation projects: (1) the physical environment, (2) the biotic environment, (3) natural disturbance/succession, (4) human disturbance, and (5) habitat scale and pattern. A summary of selected vernal pool projects in California will serve to document some of the problems.

Examples of Restoration and Creation of Vernal Pools

At least 21 projects or activities in California have focused on the restoration and creation of vernal pools (Table 1). Restoration or "rehabilitation" has ranged from the installation of fences or barriers to reduce or eliminate impacts from access (these activities also have been called "enhancements"; Ferren and Pritchett, 1988) to the removal of invasive exotic plants (Bauder, 1989a), the excavation of fill (Ferren and Pritchett, 1988), and the contouring of disturbed soil (Bauder, 1989b; Scheidlinger et al., 1984, Scheidlinger, 1988; Zedler and Black, in press). Creation projects have included the "construction" of single pools containing artificial impervious layers, a highway beautification project (Chainey, 1989), an excavation and experimental revegetation project to offset the historic loss of vernal pools (Ferren and Pritchett, 1988), mitigation projects to compensate for impacts to endangered species (Reiger, 1989; Zedler and Black, in press) and wetlands (Zentner, 1989), and pre-mitigation experiments or "pilot projects" to assess the feasibility of compensation for potential habitat loss from proposed projects (Stromberg et al., 1989; Sugnet & Associates, 1989). Several of these projects are summarized below with an emphasis on design, performance criteria, and assessment of success.

Davis Interchange, Solano County

The Federal Transportation Wildflower Program depends on methods to sustain planted wildflower communities along vegetated highway corridors (Dawson, n.d.). The Davis Interchange project was one of the first efforts to create vernal pool habitat in California. To construct viable, self-sustaining vernal pools in highway intersections for aesthetic and ecological benefits, CALTRANS funded the Department of Environmental Design, University of California, Davis, to design and implement a habitat creation project in 1986 (Dawson, n.d.; Chainey, 1989). Dawson (n.d.) proposed a hypothesis: "Through the incorporation of ecological principles into the design and construction of highway intersection development, seeded wildflower mixes will be able to establish themselves as sustainable vernal pool plant

Table 1. Vernal pool enhancement, restoration, and creation projects or activities in California

LOCATION	PROJECT SITE/TITLE	REFERENCE(S)
ALAMEDA COUNTY		
1. Berkeley	UC Botanical Garden	Roderick, 1965; Ferren and Pritchett, 1988
MERCED COUNTY		
2. Myres Ranch	Private ranch	Zedler, 1986; Ferren and Pritchett, 1988
PLACER COUNTY		
3. Roseville	Regional 65 Center	Sugnet & Associates, 1989
SACRAMENTO COUNTY		
4. Douglas Road	Sunrise-Douglas Property	Stromberg et al., 1989
5. Fair Oaks	Private residence	Ferren and Pritchett, 1988; Holland pers. comm., 1988
6. Folsom	River West Developments	Zentner, 1988; Ferren and Pritchett, 1988a,b; Zedler and Black, in press
7. Phoenix Park	Phoenix Field Ecol. Reserve	Ferren and Pritchett, 1988
8. Sacramento	Laguna Creek Assessment	Zentner, 1988
9. Sacramento	Laguna Creek Assessment	Zentner, 1988, 1989
SAN DIEGO COUNTY		
10. Del Mar Mesa	CALTRANS Property	Zedler, 1986; Zedler and Scheidlinger, 1985; Zedler and Black, in press
11. Miramar	Landfill	Zedler, 1986
12. Miramar N.A.S.	National Natural Landmark	Bauder, 1989a,b
13. Miramar N.A.S.	Interstate 15	Scheidlinger, 1985,1988; Zedler and Black, in press
14. Miramar N.A.S.	Naval Air Station	Zedler pers. comm., 1989
15. San Diego	Miramar Road	Scheidlinger et al., 1984; Zedler and Black, in press
SANTA BARBARA COUNTY		
16. UCSB West Campus	Coal Oil Point Reserve	Pritchett, 1986a,b; Ferren and Pritchett, 1988
17. Isla Vista	Del Sol Vernal Pool Reserve	Ferren and Pritchett, 1988
18. Isla Vista	Del Sol Vernal Pool Reserve	Santa Barbara County, DRM, 1989
SHASTA COUNTY		
19. Redding	Rancho Buena Vista	Zedler, 1986; Ferren and Pritchett, 1988
SOLANO COUNTY		
20. Davis	Hwy. 80 & 113 Interchange	Zentner, 1988; Dawson, n.d.
YOLO COUNTY		
21. Davis	Davis Audubon Reserve	Zedler and Black, in press Ferren and Pritchett, 1988

Table 1. Continued

FUNDING SOURCE	PROJECT ORIENTATION	ACTIVITY
1. UC	custodial, experimental	creation of 1 basin
2. -	coincidental	creation of 2 borrow pits
3. RMB Realty	Sect. 404 reulatory compliance, pre-mitigation experiment and compensation plan	creation of 82 basins in a pilot project proposed for 7.2 acres of new habitat
4. Owner/developer	pre-mitigation experiment to "assess compensation oppor."	creation of 8 basins
5. Individual	custodial, experimental	creation (artificial impervious layer)
6. Owner/developer	mitigation	creation of 3 basins
7. -	fencing to eliminate impacts	enhancement of 8-10 acres
8. City of Sacramento	pre-mitigation experiment	creation of 2 basins
9. City of Sacramento	mitigation program	restoration of 82.7 acres, creation of 44.8 acres
10. CALTRANS	mitigation for loss of endangered species habitats	creation of 40 basins
11. -	agricultural impacts	natural recovery
12. -	experimental	enhancement/restoration
13. CALTRANS	mitigation for loss of endangered species habitats	creation of 10 basins
14. USAF	mitigation	creation of 22 basins
15. Owner/developer	mitigation	restoration ("rehabilitation")
16. UCSB	mitigation, experimentation	creation of 15 basins
17. State Coastal Conserv. Calif. Conserv. Corps	compensation for historic loss	enhancement/restoration/ creation of 9 pools
18. Owner/developer	mitigation for loss of habitat on More Mesa (proposed)	restoration of 1 pool
19. Owner/developer	mitigation	creation of 1 basin
20. CALTRANS	aesthetics, experimental	creation of 12 basins
21. Private	experimental	creation of 2 basins

communities." Twelve pools were constructed in a one-acre area, formerly occupied by annual grassland, by (1) removing existing topsoil, (2) either compacting the exposed subsoil or covering the subsoil with a bentonite clay layer, (3) covering all basins with topsoil from donor natural pools that were to be destroyed as a result of another project, and (4) applying a mixture of vernal pool seed and litter to half of the pools (Chainey, 1989).

Two years of post-construction monitoring of the project have revealed that, by the end of summer 1987, average pool vegetative cover was 40% and plant species richness averaged nine species per pool, whereas in 1988, total vegetative cover was 60-70% and total plant species richness averaged 12 species per pool (Zentner, 1988; Chainey, 1989). Conclusions drawn by project participants include those of Dawson (n.d.) that (1) fully seeded pools "behave" remarkably similar to natural pools and (2) vernal pools can be "successfully" constructed for aesthetic purposes and/or reconstructed for environmental mitigation purposes, and those of Chainey (1989) that (1) compacted on-site soil with and without bentonite result in at least short-term water retention, (2) watershed to pool area ratios of about 5:1 appear to be effective in the climatic zone and soil type of the region, (3) seeding and topsoil inoculation were successful means of establishing vernal pool plants and at the end of three growing seasons no difference in seed or soil treatments were apparent, (4) rate, depth, and duration of flooding eliminated undesirable annual grasses and forbs, (5) pool depth and shape are probably not ideal for the areas based on distribution of species within pools, and (6) there was a moderately successful creation of artificial vernal pools with "imported topsoil and soil subseals." Chainey also states that it is difficult to quantify plant responses and to explain primary causative interactions, and that, "More large scale field experimentation, involving controlled and replicated conditions and treatment levels, is needed to provide more scientific basis for the prediction of successful artificial vernal pool creation methods".

Based on Dawson's hypothesis, design of the monitoring program, and the reported results, we suggest that it will be difficult to assess success of the project based on the premises of this paper, because data from donor pools and similar vernal pools in the region are apparently unavailable and because studies on water chemistry, fauna, and the functional values of artificial pools versus natural vernal pools have not been conducted. However, in addition to the goal of highway aesthetics, this project does demonstrate the ability to create at least short-term habitat for some vernal pool plant species.

Miramar Road, San Diego County.

In 1981 a project was initiated to rehabilitate degraded vernal pools on Miramar Road in the City of San Diego (Scheidlinger et al., 1984; Zedler and Black, in press). Natural vernal pools had been disturbed or nearly destroyed when the site was cleared and disced by a developer without required permits

(Scheidlinger et al., 1984). Mitigation of impacts included the designation and restoration of vernal pools at the site. Scheidlinger et al. (1984) designed an experimental rehabilitation plan that included monitoring of physical and biological attributes of five different pool treatments: (1) disturbed pools, (2) reconstructed pools, (3) reconstructed pools inoculated with seed bank material, (4) disturbed pools inoculated with seed bank material, and (5) natural pools from a different reserve.

Three years of monitoring provided the following results: (1) long or short extremes of flooding duration were disadvantageous for the growth of vernal pool plants, (2) inoculation of vernal pools with seed bank material had a dramatic effect in increasing cover, although the difference between species richness in seeded and unseeded pools was not great, (3) although pools that were both excavated and inoculated had some problems with depth and turbidity of water, certain areas of these pools had a flora indistinguishable from that in natural pools, (4) particularly sensitive plant species, such as the endangered *Pogogyne abramsii*, can be introduced successfully where suitable habitat has been created, and (5) the introduction of inoculum at sites where a natural topography had been established greatly accelerated the establishment of a vernal pool community.

Post-project monitoring following seven years of recovery revealed that three pools with favorable characteristics of water duration also are "good approximations" of natural pools with "a normal complement of vernal pool species" (Zedler and Black, in press). Although researchers associated with this rehabilitation project consider it to be successful for at least some of the pools, monitoring has been limited to physical and biological attributes and could not include on-site monitoring of natural pools because none remained after disturbance. Thus, the determination of successful rehabilitation cannot be extended to the regional ecosystem level or be made in comparison with regional examples of undisturbed natural pools.

Interstate Highway 15, Miramar Naval Air Station, San Diego County

In 1983 CALTRANS excavated 10 basins in a highway right-of-way to mitigate the destruction of natural pools that supported habitat for the endangered plant *Pogogyne abramsii*. In 1984, soil and plant material salvaged from pools destroyed during the destruction of Hwy. I-15 were deposited in the 10 basins as an experimental approach to the creation of vernal pool habitat and to the establishment of *Pogogyne abramsii* (Scheidlinger, 1985, 1988; Zedler and Black, in press). Donor pools were evaluated floristically, but no preconstruction studies were done at the creation site.

Following two growing seasons, Scheidlinger (1985) reported the following results: (1) duration of flooding was not different from natural pools of the region, (2) new basins contained a greater number of non-pool upland plants (mostly exotics) than did those in the adjacent disturbed grassland, (3) total

plant cover in the two uninoculated basins was less than 20%, and only 22% of this cover consisted of vernal pool species, (4) total cover in the eight inoculated basins ranged from 22-76% with a mean total cover of 44%, 54% of which consisted of vernal pool species, (5) total plant cover in the natural pools was 89%, 88% of which was vernal pool species, (6) *Pogogyne abramsii* appeared in all inoculated pools, (7) some species were distributed differently within the created basins as compared with natural vernal pools, and (8) some species from deeper pools with longer durations of flooding were absent from the artificial pools.

In subsequent studies, Zedler and Black (in press) and Scheidlinger (1988) report that only five of the ten artificial basins have hydrologic characteristics of vernal pools. Of these five, only one had developed a "vigorous" vernal pool flora that included a large population of *Pogogyne abramsii*. Scheidlinger (1988) applies a 12.5% "success rate" to the Hwy. I-15 project, demonstrating that higher initial results apparently did not accurately reflect long-term hydrologic and vegetative characteristics of the created basins. Once again, however, "success" of the project is limited to only monitored physical and biological attributes and apparently cannot be extrapolated to the ecosystem as a whole.

Del Mar Mesa, San Diego County

CALTRANS has implemented mitigation programs for two highway projects on Kearny Mesa by providing habitat for the endangered *Pogogyne abramsii*. One mitigation included the purchase and protection of vernal pools on a portion of Del Mar Mesa; the second mitigation included the purchase of 52 acres on which vernal pools were created (Zedler and Black, in press; Zedler and Scheidlinger, 1986). Forty artificial basins were excavated in 1986, 37 of which were inoculated with seed bank material combined from several natural pools. The created basins were compared with six natural vernal pools on Del Mar Mesa.

Zedler and Black (in press) report that, after two years of study: (1) most of the excavated basins held water as long or longer than natural pools, (2) created pools supported a representative vernal pool flora, some species of which were more abundant than in natural pools, (3) created pools had about one-half the vegetative cover and more than twice the bare ground of natural pools, and (4) recruitment of *Pogogyne abramsii* was good, but survival to maturity was low. Zedler and Black conclude that no more than 70% of the basins will evolve into "replicas" of natural pools, but that after two years only a few created pools approximated natural pools. They suggest that hope for improved conditions exists because inoculation of seed bank material was low, rainfall was not conducive for optimal vernal pool formation, and additional manipulations might improve basins with low vegetative cover.

Roseville, Placer County

A mixed-use community development is planned for Regional 65 Centre, a 1285-acre site in the North Central Roseville Specific Plan Area. Implementation of the proposed design alternative would result in the filling of 5.8 acres of vernal pool wetlands and the establishment of 128 acres of natural habitat preserves to protect 11.1 acres of wetland (Sugnet & Associates, 1989). Vernal pools of the region include a volcanic mudflow type and a lower watershed claypan type. To compensate for "unavoidable impacts" to wetlands including the loss of 5.8 acres of vernal pools, the applicant, RMB Realty, has been required to develop a detailed plan to construct 7.2 acres of vernal pool habitat. The applicant voluntarily initiated an on-site "pilot compensation project" to test, monitor, and refine wetland creation methods (Sugnet & Associates, 1989). First year results of this project were compiled as part of the application for a Federal permit to fill the natural wetlands.

"Mitigation feasibility studies" were conducted to evaluate edaphic and hydrologic conditions of the proposed "compensation sites" (Sugnet & Associates, 1989). Soil profiles were studied at 75 sample points, grading specifications were designed for each compensation site, and hydrologic budgets and runoff simulations were calculated to determine water excess on a per-acre basis; pool "micro-siting", depth, size, and species richness criteria were established using parameters developed from pre-project feasibility studies (Sugnet & Associates, 1989).

The pilot project for vernal pool creation was initated by consultants for the developer in 1988, and 82 new pools were created following the compensation feasibility studies. Pools were designed to meet specifications that fall within the natural range of physical, hydrologic, edaphic, and floristic/biologic conditions that exist on-site (Sugnet & Associates, 1989). Many pools were created by the use of check dams placed where shallow "upland swales" drain designated preserve areas, thus excavation of pool basins was not necessary. Seventy-eight dams were created: the average dimensions were 5.5 m long, 1.2 m wide, and 23 cm high. Fourteen of the 78 new pool areas were inoculated with 2-5 cm of topsoil from disturbed pools outside of the preserves, and six pools received "strip plots" of seed bank and soil material (Sugnet & Associates, 1989). Paired staff gauges were used in existing and new pools to monitor water levels and photographs were taken to record events. "Floristic success criteria" were established for the vegetation by sampling vernal pools in the study area and then by delineating two classes of vernal pools: (A) those with 10 to 19 vernal pool plant species, and (B) those with one to nine vernal pool plant species. "Comprehensive monitoring" of the pilot project is planned for five years or longer until success criteria are met, at which time the actual compensation plan will be modified before implementation in response to findings of this premitigation experiment. Floristic and invertebrate sampling and avifaunal observations were conducted during year-one.

Sugnet & Associates (1989) suggest that results of year-one monitoring reveal the new pools successfully "mimic" the hydrology of natural pools because the "behavior" of created pools appears to be within the behavior of monitored natural pools. They found that a "shift" from vegetation dominated by upland plant species to that dominated by wetland species occurred in new pools whether or not they had been inoculated with seed bank material, but that seeded pools had a slightly higher richness. They conclude that the "floristic success criteria" were met in a majority of pools the first year. Avifauna use of vernal pool habitat in the study area was "insignificant" in natural and created pools; baseline data for aquatic invertebrates was compiled but monitoring was postponed until the second year.

Although the Roseville project has multiple replicate sites for comparison and detailed soil and hydrologic sampling and monitoring, the on-site mitigation experiments occur within a natural upland/wetland habitat mosaic that may be affected adversely by the altered topography and hydrology. Although simplistic biological performance criteria may be met successfully by this project, we suggest that single criteria such as plant species richness may give no conclusive evidence for the "successful" creation of vernal pool habitat that has the functional values or even resemblance to natural on-site wetlands, or for the adequate compensation for the loss of natural wetland ecosystems.

Details of the five manipulative projects discussed above reveal the wide and generally loose application of the term "success" to imply the successful re-creation of vernal pool habitat, when in fact no project has determined this. However, projects have successfully met performance criteria or project-oriented objectives. Both of these may have little to do with the biological realities of ecosystem restoration or creation. Natural pools used for comparisons generally have not undergone the kind of disturbance that restored or created pools have undergone. Natural pools do not start from "zero" in terms of soil characteristics, seedbank composition, vegetation patterns, etc., so we do not know what they should look like or what their functional values should be in one, three, five, or more years. We can determine, however, whether they support animal life, are self-sustaining, and meet some minimally acceptable performance criteria. Our concern here is whether or not the achievement of such minimum standards is sufficient compensation for the loss of natural habitat.

Del Sol Vernal Pool Open Space and Vernal Pool Reserve

Our efforts to restore or create vernal pools have taken place in Santa Barbara County. Experimentation with manipulation of vernal pool habitat began in 1985 at Coal Oil Point Reserve, located on West Campus at the University of

California, Santa Barbara (UCSB), where 15 basins were excavated and partially inoculated with seed bank material to compensate for the loss of habitat that resulted from construction of faculty housing (Pritchett, 1986a, b). Vernal pool plants established in 2 of 15 basins, but it was shown that excessive duration of basin flooding during some years may result in the establishment of freshwater marsh vegetation rather than vernal pool habitat (Ferren and Pritchett, 1988). In 1986, the Isla Vista Recreation and Park District (IVRPD) and the UCSB Herbarium received funding from the State Coastal Conservancy and assistance from the California Conservation Corps to implement a second project known as the Del Sol Vernal Pools Enhancement Plan (Ferren and Pritchett, 1988). Del Sol Open Space and Vernal Pool Reserve, which is owned and operated by IVRPD, covers nearly 12 acres and is located in Isla Vista, a residential community adjacent to UCSB. A detailed review of the project follows.

Objectives

Objectives of the Enhancement Plan included: (1) removal of refuse, (2) installation of a barrier consisting of posts to prevent vehicular access, (3) enhancement or restoration of three existing vernal pools and creation of six new pools to compensate for the historic loss of vernal pools in the region, (4) public access and interpretive improvements, and (5) pre-project and post-construction monitoring of the Reserve and habitat manipulations (State Coastal Conservancy, 1986). Agricultural development and urbanization of the region have caused the destruction of the majority of the vernal pools evident in historical aerial photographs and have caused at least some disturbance of the remaining pools, most of which are in private ownership and threatened with impacts from residential development (Ferren and Pritchett, 1988). The Del Sol project was not a legally-required mitigation for specific impacts, but rather was designed as an experimental manipulation of habitat to test the feasibility of vernal pool restoration and creation based on techniques refined from our first project at Coal Oil Point Reserve. Unlike mitigation projects, performance criteria were not required or proposed for the Del Sol project because of its experimental nature. To evaluate the response to restoration and creation of habitat, a post-construction monitoring program was conducted that included a comparison of results from habitat manipulation with selected physical and biological attributes of natural pools of the region (Ferren and Pritchett, 1988). Post-construction resemblance of these attributes in the restored and created pools, as compared with those of regional natural pools, provided a way to evaluate the response of the manipulated habitat.

Methods

Methodology and results for pre-project monitoring, the construction phase, revegetation program, and post-construction monitoring for 1987-1988 have been reported in detail previously (e.g. Pritchett, 1988a, b; Ferren and Pritchett, 1988). Degraded pools were recontoured mechanically using a loader and

skiploader, and revegetation was accomplished through onsite preservation of vernal pool substrate adjacent to recontoured areas and through addition of seed bank material from natural vernal pools at Ellwood Mesa, which is located about 2 km west of Del Sol Reserve. New pools were created by mechanically excavating basins approximately 10 m in diameter and 30-40 cm deep, which is roughly the depth of the upper portion of the clay loam subsoil layer. Monitoring of response to manipulations included comparison of pre-project data with post-construction basin hydrology, vegetative cover, and plant species richness and relative abundance. Data were gathered along permanent transects that bisect each pool. Other observations included general descriptions of soil cores, invertebrate abundances, vertebrate use, general habitat/vegetation patterns, and occurrence of sensitive target species.

Using a transit level in spring 1989, we continued post-construction monitoring by measuring topographic relief and plant species occurrences along the permanent transects to more accurately describe and compare topography, hydrology, and vegetation patterns between natural and manipulated habitat. We proposed that comparison of selected physical and biological environmental parameters can be used to gain insight into the relationship between natural and artificial habitats. We also evaluated information from the three growing seasons to provide commentary on: (1) the determination of project "success", (2) the use of criteria such as superficial "resemblance", "functional values", and the "self-sustaining" nature of natural as compared with artificial habitat, and (3) the comparison of "cookbook recipes" versus "complex science" as the process for habitat manipulation.

Hydrology and Water Chemistry

In a comparison of created and natural pools, Ferren and Pritchett (1988) found that created pools filled more quickly after rainfall and occasionally desiccated more rapidly than natural pools, which may be due to the exposed clay subsoil, lack of decaying organic matter covering basin surfaces, and the deeper profile yet smaller size of created pools. Extent and duration of flooding in restored pools exceeded that of measured natural pools. However, extent of flooding was similar among restored and created pools, apparently because they were excavated to similar depths. Water chemistry also demonstrated differences and similarity among pools. In 1989, pH in all study pools occurred within the range 6-7 in January and 7-8 in March for pools not desiccated. Total conductivity in January, however, varied between 24 and 217 microhmos/cm, with natural or restored pools being 4-10 times the values of created pools of any treatment. The highest value (217) occurred in a restored but not excavated pool that was characterized by high perennial plant cover and an accumulation of organic material on the basin surface. Turbidity was consistently higher in the manipulated pools even after the third post-construction year, but inoculated pools, even during the first year, tended to be less turbid once vernal pool plants and aquatic invertebrates had

become well-established. Although the importance of the various differences has not been estimated or quantified, short-term monitoring has revealed differences between natural and manipulated pools.

Soils

Clay and clay loams characterized subsoils at depths of 0.5-1.5 m before excavation of created pools and one restored pool. However, some natural and enhanced pools at Del Sol Reserve are characterized by loam and sandy loam subsoils at these same depths. The donor pools at Ellwood Mesa were not tested because of logistical problems. Test results suggested that variations in pool hydrology (e.g. duration of flooding) and vegetation (e.g. amount of cover by perennial species) might be correlated with differences in subsoil conditions. Thus, vernal pools of the Santa Barbara region may be a grouping of different types of seasonal wetlands such as seeps, drainages, and basins, each of which functions as a result of local differences in surface and subsurface flows of water depending on the amount of clay in the subsoil and the slope of the land. Field observations suggest this regional relationship among habitat type, hydrology, soil, and vegetation may exist.

Vegetation and Flora

The natural pools of Ellwood Mesa had the greatest cover, 100-180%, of native vernal pool species among all monitored pools during 1987-1988 (Ferren and Pritchett, 1988). Total vegetative cover of one excavated restored pool doubled from 44% in 1987 to 90% in 1988, whereas in another restored pool it declined from 59% to 37%. Although much of the cover in restored pools was contributed by the naturalized grass *Lolium multiflorum* Lam., cover by this species in vernal pools is less during years of higher rainfall and more optimal flooding conditions. Conditions for vernal pools have been suboptimal during this three year study as a result of below average rainfall for the region and a decreased frequency of rainfall events. In the inoculated created pools, results also were mixed, but total vegetative cover was generally higher the second year (46-60%) compared to the first and was composed of largely native vernal pool species. Prior to excavation of the created basins, the grassland cover was 180% and consisted largely of naturalized grasses and forbs. Unlike the inoculated created pools, the uninoculated created pools supported a total cover composed largely of naturalized or widespread native species (e.g. *Juncus bufonius* L.) that diminished from 30-54% in 1987 to 28-30% in 1988 (Ferren and Pritchett, 1988), suggesting that inoculation was important in promoting native species.

Relative abundances (cover + density) for selected species were determined at the end of the first growing season by Pritchett (1988a, b) to quantify the vegetative response of created pools as compared with natural pools. Results demonstrated that natural pools had a higher cover of native perennial vernal pools plants (e.g. *Eryngium vaseyi* Coult. & Rose, *Eleocharis acicularis* (L.) R. & S.), whereas inoculated created pools had a higher cover of native

annual vernal pool plants (e.g. *Plagiobothrys undulatus* (Piper) Jtn., *Psilocarphus brevissimus* Nutt.). Uninoculated created pools had few or no vernal pool species, but had the highest cover values for the widespread hydrophyte *Juncus bufonius* and the naturalized weed *Erodium botrys* (Cav.) Bertol.. In 1988 and 1989, field observations suggested that native vernal pool perennials increased in relative abundance in the inoculated pools.

A floristic analysis revealed that 14 native species occurred in the two natural pools. Ten of these 14 occurred in the inoculated created pools during the first year of monitoring, and five occurred in uninoculated pools (Ferren and Pritchett, 1988). Richness of native species for each type of pool was virtually the same after three growing seasons. Although no currently recognized endemic or endangered species are known to occur presently in the Santa Barbara vernal pools, many vernal pool species (e.g. *Pilularia americana* A. Br., *Eryngium armatum* (Wats.) Coult. & Rose) are regionally rare and are threatened with local extirpation or have been eliminated previously (e.g. *Plantago bigelovii* Gray). These are "target species" that can be used to evaluate species response to manipulated habitat (e.g. Scheidlinger et al., 1984; Zedler and Black, in press). For example, *Hemizonia australis* (Keck) Keck is listed by the California Native Plant Society (Smith and Berg, 1988) as a species that might be rare and endangered but for which more information is needed to be given accurate classification. This species reaches its northern limit of distribution in the Santa Barbara region and generally occurs in the bottoms of desiccated vernal pools. Although *H. australis* occurred in the inoculated created pools during the first growing season, it was not observed in uninoculated pools until the second year. *Hemizonia australis* was common in all created pools at the end of the third growing season, demonstrating that dispersal between pools in this pool grouping apparently is important for some species and can contribute to revegetation of manipulated habitats. This species, however, is not restricted to vernal pools in the region, since it occurs occasionally in seasonally moist, disturbed soils. The ability of *H. australis* to colonize the latter habitat may account for its presence on the uninoculated basin substrates.

Topographic and Floristic Profiles

In spring 1989 we measured the topographic relief and distribution of selected species along the permanent transects that had been monitored by Ferren and Pritchett (1988) for hydrologic, vegetative, and floristic characteristics. On Ellwood Mesa, "natural" pools P and Q (Figures 1 and 2) occur within the

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Figure 1. Natural vernal pool (Pool Q): flooded, winter conditions; Ellwood Mesa, Santa Barbara County, CA.

Figure 2. Natural vernal pool (Pool Q): desiccated, spring conditions; Ellwood Mesa, Santa Barbara County, CA. Center of basin is dominated by *Eleocharis palustris* and barren, mud-cracked soil; majority of basin is dominated by *Eryngium vaseyi* and *Eleocharis acicularis*; outer dark ring is dominated by *Lolium multiflorum*.

largest grouping of vernal pools (ca. 20 pools) extant in the Santa Barbara region. Pool P is a remnant of a linear, historically-truncated, seasonal seep-like pool that apparently once flowed eastward toward a coastal pond, whereas pool Q is a relatively circular basin that is isolated from other adjacent basins in most years but can be connected to these during years of high rainfall. Profiles of these two pools (Figure 3) reveal that the basin supporting pool P is deeper (ca. 40 cm) than that supporting pool Q (ca. 30 cm). Data for both pools illustrate zonation of species from low habitats with *Eleocharis palustris* (L.)

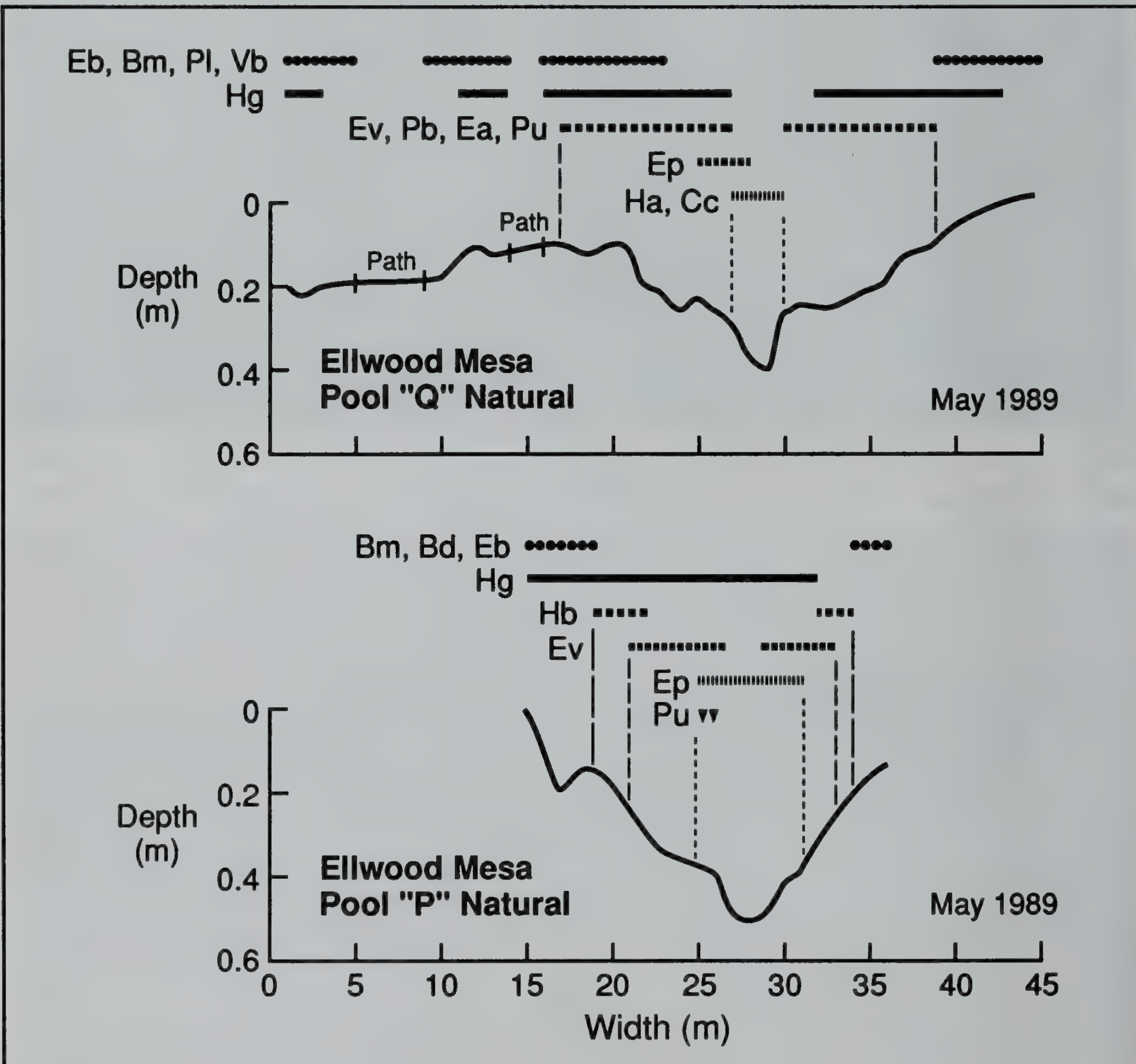

Figure 3. Topographic and vegetative profiles of natural vernal pools; Ellwood Mesa, Santa Barbara County, CA. Pool Q is photographed in Figures 1 and 2. Bd = *Bromus diandrus*, Bm = *Bromus mollis*, Cc = *Cotula coronopifolia*, Ea = *Eleocharis acicularis*, Eb = *Erodium botrys*, Ep = *Eleocharis palustris*, Ev = *Eryngium vaseyi*, Ha = *Hemizonia australis*, Hb = *Hordeum brachyantherum*, Hg = *Hordeum geniculatum*, Pb = *Psilocarphus brevissimus*, Pl = *Plantago lanceolata*, Pu = *Plagiobothrys undulatus*, Vb = *Vulpia bromoides*. Vertical exaggeration = 25x.

R. & S., a perennial spikerush common in freshwater marsh vegetation of the region, to an intermediate zone characterized by *Eryngium vaseyi* and others, and an outer zone characterized by the native perennial grass *Hordeum brachyantherum* Nevskii in the case of pool P. Other features include: (1) the annual tarweed *Hemizonia australis,* which had germinated on desiccated substrate in the bottom of pool Q, (2) *Eleocharis acicularis, Plagiobothrys undulatus,* and *Psilocarphus brevissimus,* which were common in the intermediate zone of pool Q, (3) the common and broad occurrence of *Hordeum geniculatum* Allioni., a naturalized annual barley that is generally restricted to the outer zones of pools when optimal rainfall conditions cause greater extent and duration of flooding, and (4) upland annual grassland beyond the outer margin of the pools and characterized by numerous naturalized annual grasses and forbs.

Flooding, desiccation, and vegetation patterns in restored pools (Figures 4 and 5) were similar to those observed in natural pools (Ferren and Pritchett, 1988). Transect data from restored pool E at Del Sol Reserve in 1989 illustrates two sub-basins produced as a goal of contouring the land during restoration (Figure 6). At the end of the third growing season for most vernal pool species, *Eleocharis palustris* was restricted to the bottom of each sub-basin (Figure 6), *Eleocharis acicularis* and *Eryngium armatum* occurred across the basin, but visual observations indicate they were more abundant and had greater cover in the intermediate zone, and *Hordeum brachyantherum* occurred in the outer zone with *Hordeum geniculatum* and *Lolium multiflorum,* two naturalized annual grasses.

Vegetation patterns in created pools (Figures 7 and 8) were similar to those in natural pools only when the created pools had been inoculated with seed bank material (Ferren and Pritchett, 1988). Transect data from created pools in 1989 illustrate three different responses to recovery of vegetation near the end of the third growing season (Figure 9). Created pool M was inoculated with seed bank material combined from natural pools P and Q. Although the data indicate broad overlap in species distributions, the visual impression is that the vegetation is zoned, with an overall pattern of *Eleocharis palustris* in the lower or central zone to *Hordeum brachyantherum* and *H. geniculatum* in the outer zone. Domination of pool habitat by native species is striking for a suboptimal rainfall year (Figure 10), even when compared with natural pools at Ellwood Mesa. Vegetation response in inoculated pool L (Figure 9) was different than in pool M, possibly because of differences in excavation. In pool L, slope angle was less steep, pool bottom was broader, the excavated basin was shallower, and no clay loam was exposed in the bottom as compared with other created pools. These factors are correlated with flooding of shorter duration and vegetation with a greater density of naturalized species, less evidence of zonation of vegetation, and fewer native hydrophytes than in other inoculated created pools (Ferren and Pritchett, 1988).

Figure 4. Restored vernal pool (Pool E): flooded, winter conditions; Del Sol Reserve, Santa Barbara County, CA.

Figure 5. Restored vernal pool (Pool E): desiccated, late spring conditions; Del Sol Reserve, Santa Barbara County, CA. Center of basin is dominated by *Eleocharis palustris* and barren soil; majority of basin is dominated by *Eleocharis acicularis* (low, fine-textured vegetation); tall grass on irregular margin of basin is *Lolium multiflorum.*

Both inoculated pools M and L, however, are quite a contrast to created pool J, which was not treated with inoculum and lacked most vernal pool species along the sampled transect (Figure 9). Zonation is evident, however, with a small patch of *Eleocharis acicularis* and scattered seedlings of *Hemizonia australis* colonizing the bottom, *Juncus bufonius* forming a dense intermediate ring, and *Lolium multiflorum* occurring as an outer zone transitional to upland grassland. Although scattered individuals of several vernal pool species do occur in the uninoculated pools, their densities are low

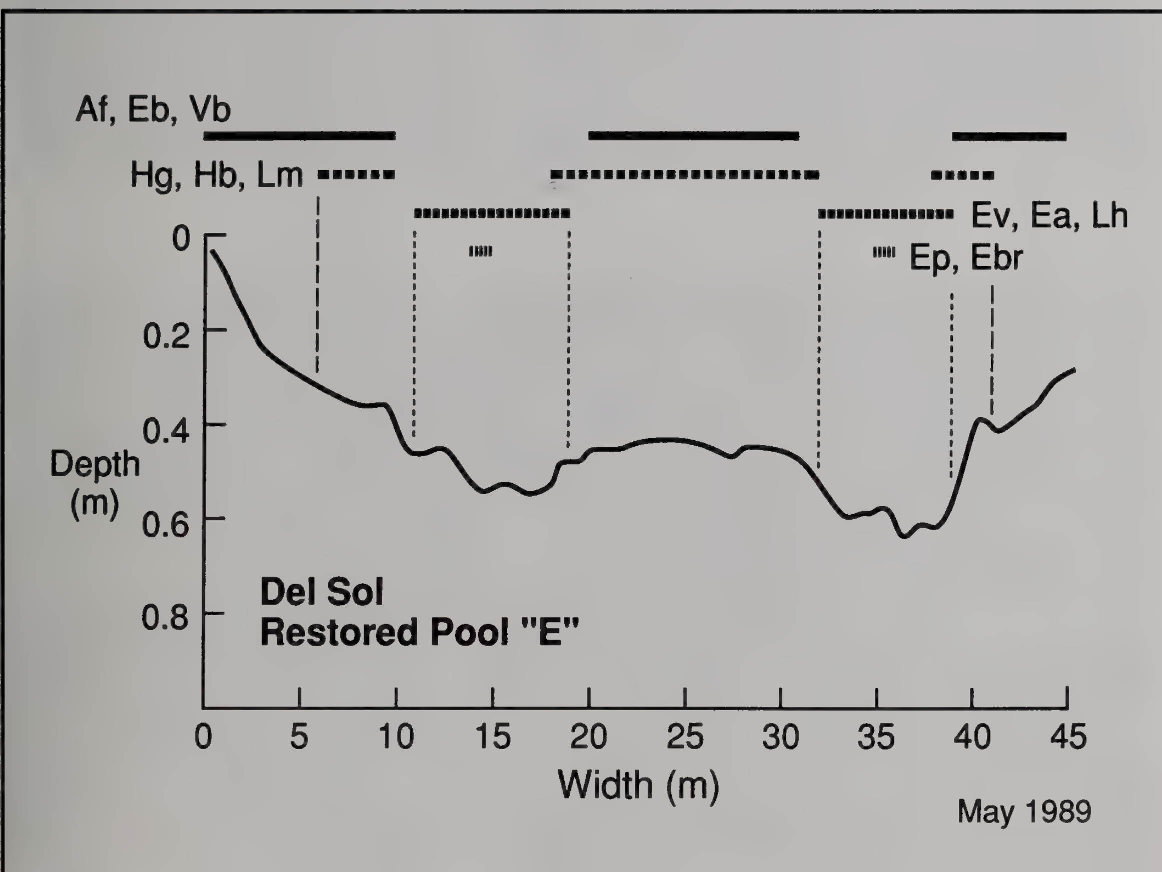

Figure 6. Topographic and vegetative profile of restored vernal pool (Pool E); Del Sol Reserve, Santa Barbara County, CA. Restored pool E is photographed in Figures 4 and 5. Af = *Avena fatua*, Ea = *Eleocharis acicularis*, Eb = *Erodium botrys*, Ebr = *Elatine brachysperma*, Ep = *Eleocharis palustris*, Ev = *Eryngium vaseyi*, Hb = *Hordeum brachyantherum*, Hg = *Hordeum geniculatum*, Lh = *Lythrum hyssopifolia*, Lm = *Lolium multiflorum*, Vb = *Vulpia bromoides*. Vertical exaggeration = 25x.

and may not increase because of competition with species such as *J. bufonius* and *L. multiflorum*.

Fauna

Vertebrate use of manipulated pools appeared similar to that of natural pools. Teals, mallards, greater yellow-legs, common egrets, great blue herons, meadowlarks, black-shouldered kites, common snipes, and many other birds were observed visitors to the Del Sol vernal pool and grassland ecosystem. Although bird use of the Reserve may not be restricted to one particular habitat, ducks apparently come to the reserve because of the larger natural, and restored vernal pools, rather than for the smaller created pools. Pacific tree frogs have reproduced successfully in all types of study pools. For each of the three years of post-construction monitoring, invertebrates have occurred in far greater numbers in inoculated restored and created pools than in uninoculated created pools. In 1987 for example, ostracods occurred in numbers one hundredfold greater in inoculated created pools than in uninoculated created pools, suggesting that invertebrates as well as plants were introduced when seed bank material was added to new basins (Ferren and Pritchett, 1988).

Analysis

Three years of post-construction monitoring reveal that: (1) restored and created pools support native vernal pool plants with vegetational patterns similar to natural vernal pools; (2) restored and created pools are to this time self-sustaining; (3) inoculation of created pools is essential to maximize similarity with natural pools in the short run and possibly also in the long run; (4) restored and created pools do not resemble natural pools in species cover and abundance during short-term analysis; and (5) observations support the view that functional values such as food chain support and role of pools in a grassland setting are probably similar among natural, restored, and inoculated created pools. Thus, short-term monitoring of manipulated pools in the Del Sol experiment revealed that project objectives are being met. We conclude that there is at least short-term "project" success (i.e. we met project objectives), but there is still no conclusive evidence (e.g. long-term establishment of habitat functional values) that we have successfully restored or created vernal pool habitat that is identifiable as a community within the range of variability of natural pools of the region. Our "recipe" for

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Figure 7. Created "vernal pool" (Pool M): flooded, winter conditions; Del Sol Reserve, Santa Barbara County, CA.

Figure 8. Created "vernal pool" (Pool M): desiccated late spring conditions; Del Sol Reserve, Santa Barbara County, CA. Center of basin has some barren, exposed, clay subsoil; majority of basin dominated by *Eleocharis acicularis*, *Eryngium vaseyi*, and *Psilocarphus brevissimus*. Outer ring of basin characterized by *Hordeum brachyantherum* and *Lolium multiflorum*.

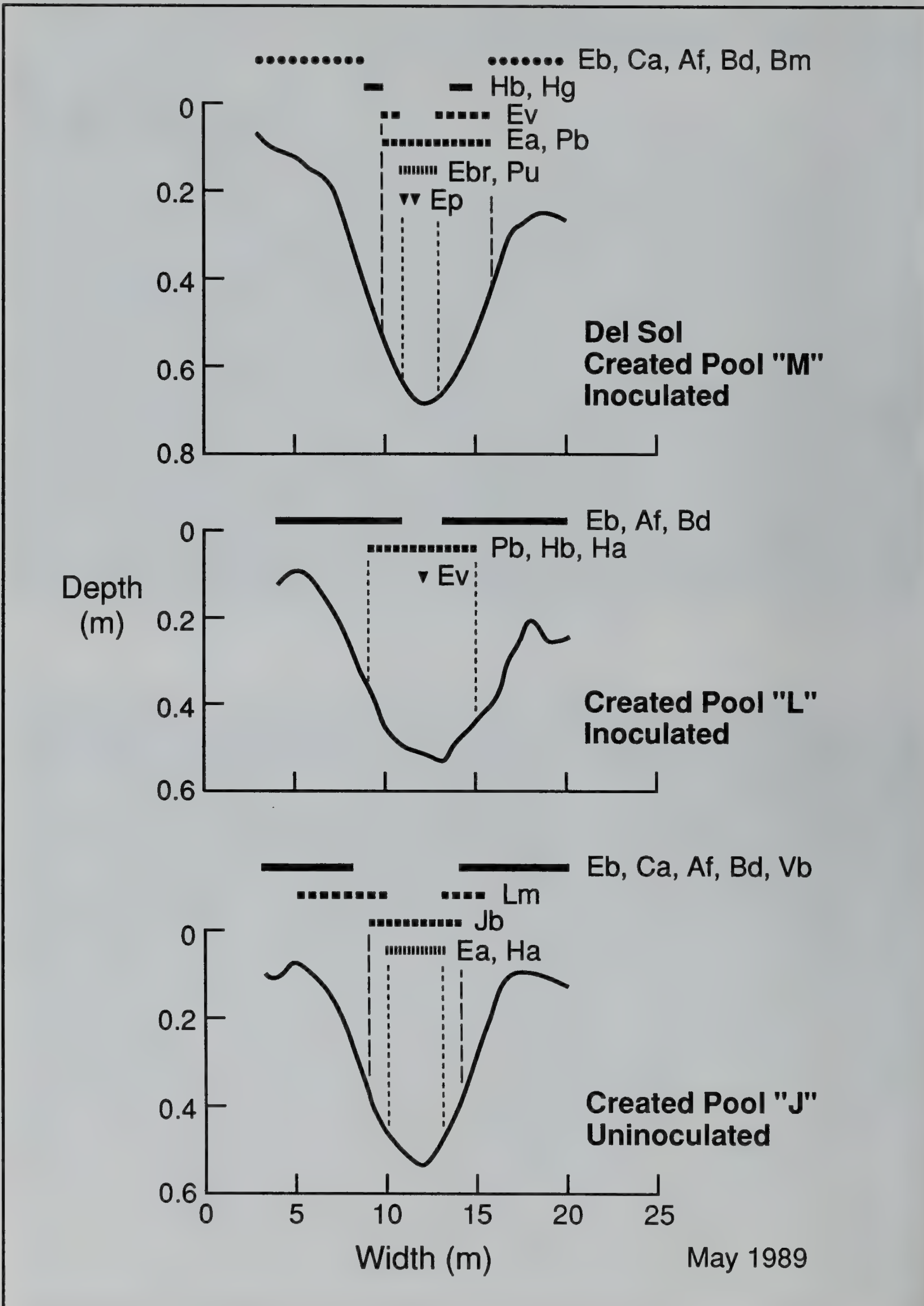
Eb, Ca, Af, Bd, Bm
Hb, Hg
Ev
Ea, Pb
Ebr, Pu
Ep
Del Sol
Created Pool "M"
Inoculated
Eb, Af, Bd
Pb, Hb, Ha
Ev
Depth
(m)
Created Pool "L"
Inoculated
Eb, Ca, Af, Bd, Vb
Lm
Jb
Ea, Ha
Created Pool "J"
Uninoculated
0
0.2
0.4
0.6
0.8
0
5
10
15
20
25
Width (m)
May 1989

Figure 9. Topographic and vegetative profiles of three created "vernal pools"; Del Sol Reserve, Santa Barbara County, CA. Pool M is photographed in Figures 7 and 8. Pool M and L were inoculated with seed bank material removed from natural vernal pools. Pool J was not inoculated with seed bank material. Af = *Avena fatua*, Bd = *Bromus diandrus*, Bm = *Bromus mollis*, Ca = *Convolvulus arvensis*, Ea = *Eleocharis acicularis*, Eb = *Erodium botrys*, Ebr = *Elatine brachysperma*, Ep = *Eleocharis palustris*, Ev = *Eryngium vaseyi*, Jb = *Juncus bufonius*, Ha = *Hemizonia australis*, Hb = *Hordeum brachyantherum*, Hg = *Hordeum geniculatum*, Lm = *Lolium multiflorum*, Pb = *Psilocarphus brevissimus*, Pu = *Plagiobothrys undulatus*, Vb = *Vulpia bromoides*. Vertical exaggeration = 25x.

Figure 10. Created vernal pool (Pool M): desiccated, late spring conditions; Del Sol Reserve, Santa Barbara County, CA. Center of pool (left) includes a view of exposed, mud-cracked, clay subsoil. Vernal pool vegetation is dominated by native species, including vernal pool endemics [e.g. *Eryngium vaseyi* (rosettes) and *Psilocarphus brevissimus* (white spots)].

manipulation (excavation + seed bank material + rainfall) has yielded promising results, but these results are identifiable only because of a technical and scientific approach to project design, monitoring, and analysis.

Habitat Manipulation: Pitfalls, Problems, Solutions

The "cookbook recipe" in addition to "complex science" approach to restoration and creation of vernal pools must go beyond the design, implementation, and monitoring of projects. The identification, analyses, and solutions to pitfalls and problems encountered during the process could be keys to the long-term "success" of habitat manipulation. The 21 projects or activities listed in Table 1 or discussed above give us some evidence as to the complexity of the manipulation process.

Performance Criteria

Although we need more independent experimentation on manipulation of vernal pool habitat to document the inter-relatedness of the physical and biological aspects of habitat alteration rather than agency-required and developer-funded mitigations and mitigation experiments, performance criteria should be an integral part of the overall process. These criteria may be expressed in the form of scientific hypotheses or mitigation success requirements, but there must be rigorous standards by which we analyze our results or judge mitigations. However, these standards should be of a framework nature, with adequate flexibility to incorporate environmental variables (e.g. inconsistent weather patterns) and local ecosystem characteristics (e.g. potential widespread herbivory). The Del Sol project, for example, had specific objectives, pre-project evaluations, and post-construction monitoring. The latter included evaluations such as comparisons among pools, experimental revegetation work, and use of natural reference pools. However, no quantitative performance criteria were established. The experimental nature of our work rather than a required mitigation makes the need for performance criteria less significant because the questions asked are more related to what happens rather than how much of a response occurred over what period of time. A real pitfall of many mitigation projects, including those previously discussed, appears to be the establishment of simplistic mitigation performance criteria that must be achieved during a specific monitoring period, rather than criteria aimed at determining whether natural vernal pool ecosystems have been re-created. This non-rigorous, deadline approach to performance criteria lacks the flexibility and detail discussed above and, therefore, may prevent us from knowing if destruction of natural habitat has been compensated adequately by new habitat. Alternatively, "framework" success standards should incorporate functional characteristics of ecosystems (e.g. vegetation patterns, food chain support values, role of the habitat within a larger system) that can be monitored over long periods and with analysis that considers annual variation of many environmental parameters.

Monitoring Programs

Although pre-project studies have been conducted for many recent projects, "Pre-project Monitoring Programs", including that for Del Sol Reserve, rarely involve monitoring, but rather are site evaluations to establish pre-project "baseline" conditions that exist for a point in time. Thus, extensive and varied data for sites that are to be manipulated generally do not exist before a project is proposed, and are rarely obtained as a product of the project. Because the restoration and creation of vernal pools is a relatively new practice, data from long-term post-project monitoring programs are generally unavailable. This lack of information presents a serious problem because an increasing number of residential, commercial, and industrial developments include the destruction of natural habitat and the proposed restoration or creation of vernal pools to mitigate the loss of habitat. There is little or no evidence to date that suggests mitigations are a guaranteed success, particularly because the monitoring data that do exist come from various parts of California, and from vernal pools with different origins, different biota, and different physical parameters.

Rarely do projects of habitat manipulation and mitigation include sufficient funds to evaluate the habitats from an integrated ecosytem approach rather than an organismal approach. Although many projects demonstrate that manipulated pools can support vernal pool plant species, the same projects generally provide no evidence to suggest whether the pools actually have functional values within the range of on-site, like-kind natural vernal pool ecosystems. Fortunately, recently implemented mitigation projects such as those in the vicinity of Sacramento and San Diego include many improvements in monitoring designs. However, a lack of compatibility among programs and techniques compounds the problem of evaluation and comparison of projects.

Interpretation of Results

Effects of restorational and creation projects are subject to numerous environmental and regulatory influences that can mask the results of short-term post-construction monitoring. Amounts and patterns of seasonal rainfall, for example, have been one of the more problematic and unpredictable effects on projects in southern California. In general, monitoring of projects has occurred during years when the rainfall pattern permits pools to desiccate between storms. These conditions favor introduced weedy species in the shallow pools and could even obscure the long-term positive effects of a project that might exist during optimal patterns of rainfall.

Other events that can influence results include, for example: (1) herbivory on vernal pool plants by rodents when pools are created in the vicinity of chaparral vegetation (Zedler, pers. comm., 1989), (2) source and quantity of seed bank material, (3) access programs that could disturb the recovering or

establishing wetland species, and (4) mosquito abatement practices required by some agencies (Ferren and Pritchett, 1988). In the end, many events beyond the control of a monitoring study could influence the decision on the effectiveness of an experimental or mitigation project. The difference between project success, based on achievement of performance criteria, and actual re-creation of ecosystems may be as great or narrow as the quality and quantity of the criteria and the rigor of the monitoring program that measures them.

Conclusions

We return to the question raised at the beginning of this paper: *Should the potentially successful efforts to manipulate the environment (e.g. vernal pools) be based only upon "cookbook recipes", or should they also be the result of complex scientific and techological processes?* Some researchers believe that if enough manipulation is done, the restored or created product eventually will "resemble" a natural vernal pool. For example, the three inoculated created pools at Del Sol Reserve appear to be responding toward resemblance of natural pools based on our observations during the past three years. Zedler (1989), however, suggests that "self-sustaining habitat" may be possible to create, but it may not be "like" natural habitat. Given that plants and animals restricted to vernal pools have adapted to natural habitat that formed over long periods, we agree with Zedler, because the intricacies of the relationships between natural vernal pool habitat and vernal pool organisms may never be understood to the degree that we will know if we have re-created them. For the scientific and regulatory communities to adequately evaluate the results, the process of habitat manipulation must draw from the increasing body of scientific and technological knowledge regarding thorough pre-project evaluations, construction and revegetation plans, and post-construction monitoring. Furthermore, careful post-project planning is essential to protect, monitor, and manage the restored and created habitats in perpetuity. This is particularly important when the habitat manipulations are mitigation for impacts from agency-permitted development, because if impacts from urbanization last forever, why shouldn't the mitigation? Zedler and Black (1989a) are correct when they caution that, "...although artificial habitat can supplement or replace natural habitat it will never become natural habitat." We emphasize this point by suggesting that the environment to which organisms have adapted through the course of evolution may never be replicated or restored in a manner that would foster their potential for continued evolution in the same way that natural habitat would foster it.

In spite of these obstacles, which will be difficult to overcome, we believe the answer to the recipe/science question is that a formula or "recipe" for habitat restoration and creation may be possible for each geographic region in which

vernal pools occur. However, each recipe will be determined only as a result of science, technology, and planning, all of which are essential to determine the "success" of a project, as defined by detailed but flexible performance criteria that take into account the many environmental factors that can effect results.

Having concluded that the process of restoration and creation of vernal pools should be the result of scientific and technologic processes, we return to the hypothesis presented previously in this paper: *that vernal pools can be restored or created to provide functional values within the range of variability of natural pools.* We find there is presently no conclusive evidence to suggest that this hypothesis, or some variation of it, has been proven. Furthermore, because of the many uncertainties and observed failures, there is a widespread concern among investigators and regulators that restoration and creation of vernal pools must be viewed as experimental and should not be used as mitigation of impacts without a more thorough understanding of natural pools and the potential to reproduce them. Zedler and Black (1989b) caution further that, "...if we eliminate all natural habitats the link between local environment, history, and geographic locality will be lost or badly muddled." Above all other management priorities, preservation of the remaining "pristine" pools from each region, and the avoidance of natural habitats during the design of developments, should be primary objectives at all levels of planning. Otherwise, how will we know that habitat manipulation has approximated natural vernal pools if, eventually, there are no acceptable examples with which to compare the artificial ones? As emphasized directly and accurately at a vernal pool symposium (Cochrane, 1989), "If we have not reproduced a system in its entirety, then we have lost the resource!" There is a challenge for all of us to prevent the further loss of vernal pools and other types of environmentally sensitive habitats.

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Wayne R. Ferren Jr.
The Herbarium
Department of Biological Sciences
University of California
Santa Barbara, CA 93106

Elihu M. Gevirtz
The Herbarium
Department of Biological Sciences
University of California
Santa Barbara, CA 93106

Ferren Jr., W. R., and E. M. Gevirtz. 1990. Restoration and creation of vernal pools: cookbook recipes or complex science? *In* D. H. Ikeda and R. A. Schlising [eds.], Vernal pool plants–their habitat and biology, 147-178. Studies from the Herbarium No. 8, California State University, Chico.

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